Securing cyberspace: development and evaluation of a novel research toolset

A thesis submitted for the degree of Doctor of Philosophy (PhD)

by

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Declaration

Candidate's declarations:

I, Samuela Bolgan, hereby certify that this thesis submitted in partial fulfilment of the requirements for the award of Doctor of Philosophy (PhD), Abertay University, is wholly my own work unless otherwise referenced or acknowledged. This work has not been submitted for any other qualification at any other academic institution.

Signed

Date

Supervisor's declaration:

I, Dr. Elena Rusconi, hereby certify that the candidate has fulfilled the conditions of the Resolution and Regulations appropriate for the degree of Doctor of Philosophy (PhD) in Abertay University and that the candidate is qualified to submit this thesis in application for that degree.

Signed

Date

Certificate of Approval

I certify that this is a true and accurate version of the thesis approved by the examiners, and that all relevant ordinance regulations have been fulfilled.

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Dedication

To Moira and Arnaldo,

Mum and Dad,

I owe it all to you.

Abstract

Cybersecurity is an issue of great concern today; data breaches are becoming more frequent and are causing huge economic losses in almost all the industry sectors. The majority of them are caused by malicious or criminal attacks perpetrated by individuals also known as “hackers”. Although the mainstream portrait of hackers nowadays brings to mind the idea of cybercriminals, not all hackers are malicious ones. The word hacker in its original sense only describes a computer enthusiast and a skilled programmer who was eager to learn how computers work. The key to distinguish a good or a bad hacker lies only in the specific intent and the permission to hack. Recently many companies are indeed hiring hackers to test their systems and protect them from the malicious attacks. The strength of good hackers is that they possess the same skills as malicious ones but they use them to enhance security. At the present stage, the process of hiring candidates for internet security positions for the majority of organizations, and business corporations relies mainly on interviews, while few of them advertise some sort of hacking challenges to be solved by potential applicants in order to evaluate upfront their skills and abilities. Moreover, an in-depth review of the literature has revealed that, so far, no systematic investigation has been carried out on the cognitive skills that characterise ethical hackers, experts who are professionally trained to protect systems’ security. The present PhD thesis offers a contribution that starts filling this gap in the literature with an exploratory investigation on the cognitive skills related with hacking expertise on a behavioural level. Findings show that hackers possess stronger systemizing traits as compared to the general population, and suggest a role of the ability to systemize on hacking performance. Moreover, performance on hacking-related tasks is shown to be related with mental rotation abilities and a field independent cognitive style. These findings have both theoretical and practical applications that are extensively discussed; together with possible future directions.

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Glossary of terms

Neurotypical: Within the field of autism, neurotypical is an abbreviation of neurologically typical and it is used to indicate individuals who are not in the autistic spectrum

Subclinical: a condition with no clinical symptoms; i.e. without any detectable signs or symptoms.

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1 INTRODUCTION

Computer security is a major concern for companies, government, businesses and industries. Systems are constantly exposed to many different threats and the losses in terms of data and money are increasing year after year. Usually companies, governments and all the end-users have relied on a reactive approach to face the computer security issues by installing and updating antivirus, firewalls and anti-malwares. Nowadays this approach has been proved to be ineffective, as new viruses and malicious software are released every day and the vendors are not able to keep their antiviruses, firewalls, antimalware up do date. Another approach has emerged recently, a proactive approach, which consists in hiring the so called “ethical hackers” to penetrate one’s own computers system, find vulnerabilities, and fix bugs. Ethical hackers are certified experts trained to keep systems secure by monitoring networks, fixing bugs and other related issues. Their value is that they have similar abilities and skills as malicious hackers and are trained to think the same way so they can efficiently test the vulnerabilities in computer systems. In this chapter the two perspectives on hackers – as malicious intruders and as a way to protect the computer systems – are introduced.

1.1 Hacking as a security threat

Computer systems are pervasive in our society, they are used in everyday life, from business to banking, from entertainment to healthcare, and most of these systems are interconnected (Arief & Besnard, 2003). Individuals, institutions, and governments have all found themselves targeted by hackers at various points. According to the 2014 Information Security Breaches survey, commissioned by the UK Department for Business Innovation and Skills, the overall cost of security breaches for all types of organisations had nearly doubled since 2013. It was estimated that 55% of large businesses were attacked by an unauthorised outsider in 2014. The average cost to these large organisations of the worst security breaches of 2014 has been estimated at £600k-1.15m. Security breach levels decreased slightly compared to the previous year but were much more costly. Moreover, given that 70% of organisations keep their worst security incident under wraps, these figures may just show the tip of the iceberg (Department for Business, Innovation & Skills and The Shareholder Executive, 2014). Attacks are not directed only to large organizations and corporations. Cybercriminals may direct “ransomware” attacks to easy targets such as small business and individual computer users. This type of attack consists in encrypting files so the user cannot access them unless he or she pays a ransom. CryptoLocker boasted a 41% success rate (i.e. more than 1/3 of the victims paid the ransom) and it has been estimated that the virus made attackers earn between $3 million and $27 million[1]. In 2014 more than 625,000 computers worldwide were infected by another ransomware, CryptoWall. As recently as in May 2017, a ransomware called WannaCry infected a large numbers of computers of the British National Health Service, as well as computers in Spain, Ukraine and Taiwan, encrypting the data and asking for a ransom to release the key to decrypt them.

Thus, threats to information security are a major concern for both individuals and organizations and hacking is one of the most recognised and feared threats in cyberspace (Furnell, 2002). The natural escalation of offensive threats has showed that, in practice, no system is safe. It is increasingly difficult to protect key information assets and infrastructure in the face of a technology that is constantly evolving. Recently, the Ponemon Institute released the 2016 Cost of Data Breach Study, a global analysis comprising of 383 companies in 12 countries. According to the report, the average total cost of data breach is $4 million and the average cost per lost or stolen record is $158. Since 2013 there has been a 29% increase in the total cost of data breach. Almost half of the total data breaches was caused by malicious or criminal attacks (48%), the other half being caused by system glitches (27%) and human error (25%) (Ponemon Institute, 2016). The common technological measures adopted to counteract hacking activities (e.g. anti-virus, firewalls, etc.) are defensive and fundamentally imperfect (Button, Wang, Klahr, Amili, & Shah, 2016). These rely on technologies that attempt to identify known, broadly distributed attacks with recognizable patterns.

1.2 Hacking as a security tool

Labuschagne and Eloff (2000) identified two main approaches to information security: a proactive approach and a reactive approach. Most organizations adopt a reactive approach as the vulnerability of systems is usually evaluated after an attack takes place, resulting in money spent on fixing the security holes and recovering from

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[1] http://time.com/4303129/hackers-computer-ransom-ransomware

the data and business loss. This is the least effective and more expensive approach (Sukhai, 2004). The proactive approach consists of trying to locate security holes before the attacks take place and is called “Ethical Hacking” (Sukhai, 2004). The raison d’être of an ethical hacker is to try to determine what an intruder can see on a targeted network or system, and what the intruder can do with that information. Ethical hackers use the same software tools that malicious hackers use, seeking to improve the security of the network by proactively attacking it as a malicious attacker would (Munson, 2009). The process of testing the security of a system or network is referred to as penetration testing (or “pen testing”; Graves, 2010). In recent years, many have advocated the importance of having experienced professionals to probe organisations using penetration testing (see e.g. Glenny’s TED talk “Hire the hackers!”;http://www.ted.com/talks/misha_glenny_hire_the_hackers#t-241927). Ethical hackers are becoming a mainstay of the effort to make corporate networks more secure and several companies ranging in size from small start-ups to large corporations have ethical-hacking teams (Price, 2015). Nevertheless, there is not an effective selection strategy specifically developed to detect the most desirable candidates for this job.

While the interview is often considered the best method for evaluating applicants (e.g. Subramanian & Joshi, 1996), there is the need to develop reliable screening tools to add performance data to it. The selection process can gain remarkable benefits from the use of aptitude tests and behavioural measures to evaluate an individual’s skills, potentials and cognitive characteristics. An interview could reveal verbal and communication skills but it may not necessarily probe the breadth of cognitive abilities and skills that are necessary for the job (Subramanian & Joshi, 1996). Ownby, Czaja, Loewenstein, and Rubert (2008) suggested that a brief battery of cognitive measures may be useful in evaluating individuals for job selection. More recently, corporations, agencies and organizations began to use so called “challenges” as a means to find the best applicants for information security jobs (see e.g. GCHQ’s www.canyoucrackit.co.uk). British Telecom takes part in a number of hackathon-style “war-game” competitions, such as Cyber Security Challenge UK and the international Cambridge 2 Cambridge cyber security challenge, to identify the most talented individuals. In such competitions, contestants take part in simulations of cyber-attacks pitting their skills against other participants, to see who has the strongest cybersecurity skills[2].

Recently Cybrary, the world's first and only no-cost cyber-security open online course provider announced the results of its *Cyber Security Job Trends Survey for 2016* completed by 435 senior-level technology professionals from companies around the world. Of interest nearly 25% of the companies declared they have not yet figured out the best way to recruit cybersecurity experts.

1.3 Aims of the thesis

The present thesis aimed to provide an insight on the cognitive skills that might relate with hacking expertise. On one hand the findings might be used as a starting point to further investigate specific abilities that can correlate with hacking thus contributing at filling the present gap in the literature. On the other hand results from this thesis, with further investigations, might have a potential implication in developing more reliable evaluation tools to help the process of hiring applicants for ethical hacking positions by identifying peculiar skills that could be assessed. This research project is characterized by a novel approach, as it is an interdisciplinary research project between cognitive psychology and ethical hacking. The novelty regards mainly the fact that no prior investigation has been made on the cognitive skills that might predispose to hacking expertise. The main effort of this PhD was to try to build a bridge between two different fields of research – cognitive psychology and ethical hacking – starting from communalities identified in the literature review. In fact, the novel approach that characterizes this thesis rests on empirical bases and the objectives and aims of the project were formulated on the basis of findings from previous studies. At the very beginning literature belonging to two different lines of research was reviewed: psychology of programming on one hand and research on systemizing ability on the other. As it will be discussed in Chapter 3, literature on the psychology of programming is relevant for this PhD because programming is a prerequisite of hacking, while literature on systemizing is relevant because findings from recent studies suggest that the concept might be linked with hacking expertise. The originality of the thesis lies in the effort to combine together findings from different research fields, formulate new

2 http://home.bt.com/news/bt-life/bt-recruiting-900-people-for-security-business-11364051539458

hypotheses to be tested and develop an original research design to gather some initial information on the cognitive skills that can relate with hacking expertise. In order to do so, a novel measurement instrument was created to assess specific traits that, according to the literature, characterize hackers: problem solving and curiosity. The instrument was a self-report questionnaire developed within the first year of the PhD accordingly with the guidelines provided by the international experts of survey methodology. A detailed description of the development and the initial testing of the self-report questionnaire is provided in Chapter 4. The novelty of the approach and of the assessment instrument are based on existing empirical bases as the hypotheses posited at the beginning of the present PhD were formulated according to a thorough literature review, discussed in Chapter 2 and Chapter 3.

The main objectives of the thesis are:

a. review the relevant literature on hackers and on the cognitive skills related to programming proficiency (on the assumption that programming is a crucial prerequisite of hacking expertise);

b. identify individual traits and a specific cognitive style that could characterise hackers;

c. operationalise such traits and cognitive style, and create behavioural and self-report measures for hacking-like and expert hacking skills, to allow hypothesis testing in both the general population and in hackers;

d. Analyse the pattern of individual differences and the statistical association between cognitive skills and ethical hacking expertise or predisposition.

The above aim was accomplished by developing a battery of new tests which comprised: 1) the Systemizing Questionnaire, 2) a novel scale, 3) the Raven Matrices Short Version, 4) the Mental Rotation Test, 3) a Visual Working memory test, 4) the Navon Task, 5) the Group Embedded Figure Test, 6) a Steganography Task, 5) a Hidden words search and a crucipuzzle tasks , 6) a hacking challenge. The battery was administered to the general population and to hackers in order to look for individual differences and correlations among the different measures. The battery was then administered accordingly to a between subject design, to a sample of hackers and non-hackers. Chapter 5 and Chapter 6 provide the rationale behind the choice of the tasks and a detailed description of all the above mentioned measures.

The main hypotheses that guided the data collection were:

- Hackers might have a strong drive to systemize and this may result in higher scores on self-report measures of systemizing compared to the general population;
- Hackers might possess strong problem solving skills and this may result in higher scores on a novel scale developed *ad hoc* compared to the general population;
- Cognitive abilities such as mental rotation and visual working memory might be related with hacking skills;
- A field independent cognitive style might be related with hacking skills;

1.4 Conclusion

In this chapter a new perspective on hackers was discussed. When hackers are trained and/or willing to use their skills in an "ethical" way, they are now considered an invaluable resource to protect computer systems. Indeed, the classical automated methods relying on firewalls and antiviruses demonstrated their inefficiency: the speed in which new security threats are released is so fast that these can seldom keep up to date with them. For this reason, companies, businesses and governments are hiring ethical hackers to penetrate into their systems and keep them secure by discovering potential ways in fixing vulnerabilities and enhance the security of the systems.

To date, nevertheless, there is no established selection tool when it comes to hire potential candidates for the position of ethical hackers. The classical methods, such as interviews and hacking challenges, say nothing about whether the candidates do possess the cognitive skills required for the job. The present thesis aims to provide new insights on to the cognitive abilities and the cognitive styles that might be related with hacking expertise. This has basic implications in the development and understanding of broad psychological constructs like systemizing and field independence, and offers a practical contribution to the recruiting process by highlighting target cognitive skills that may be looked for in applicants.

The main objectives and aims of the thesis were presented together with the initial hypotheses that guided the data collection. The novelty of the approach was underlined, and the empirical bases on which the study was developed were briefly explained. In the following chapters the empirical findings on which the thesis lies are presented and discussed. Chapter 2 reviews the literature on the cognitive psychology of programming and how the research findings were applied to the development of aptitude tests. This literature is of relevance for the present thesis because programming is a prerequisite of hacking. Chapter 3 discusses the recent established link between hacking and positive traits of autism such as attention to detail and the concept of systemizing. reviews the literature on systemizing and explore the hypothesis that the concept might be used to investigate the cognitive correlates of hacking expertise. Chapters 4, 5 and 6 describe the three studies conducted by myself to investigate the hypotheses formulated after the literature review. In Chapter 7 the findings of the studies are summarized and discussed in light of the literature; limitations of the present thesis are acknowledged and future directions are suggested.

2 EXPLORING RESEARCH ON HACKERS AND PROGRAMMERS

2.1 Introduction

In this chapter literature that is relevant to investigating the psychology of hackers is reviewed. Hackers are here defined as individuals who enjoy exploring the details of programmable systems and identifying those systems' vulnerabilities. The majority of studies focused on personality traits and motivations behind the choice to hack while fewer studies addressed the cognitive skills related to hacking expertise. In the second part of the chapter the focus of the literature review will be on research on the cognitive skills involved in computer programming, which is related to hacking skills; how these skills have been measured in personnel selection will also be addressed. A discussion on differences and communalities between hackers and programmers will clarify and qualify the relevance of the literature on programmers to that on hackers.

2.2 Hacking and hackers

2.2.1 Definitions

The term "hacking" does not have a single definition (Gunkel, 2000). The origin of hacking can be traced directly to the development of computer technology at the Massachusetts Institute of Technology (MIT) in the 1950s. The name was used to refer to programming shortcuts to make things run quicker or better (Lilley, 2002). Initially, therefore, the word "hacker" was used to refer to an individual skilled at interacting with computers and "had strong laudatory connotations of deep knowledge driven by insatiable curiosity" (Bratus, 2007, p.2). That is still the meaning enshrined in the 1994 edition of the New Hacker's Dictionary[3], which defines a hacker as "someone who enjoys exploring the details of programmable systems and how to stretch their

[3] http://www.catb.org/jargon/html/H/hacker.html

capabilities; one who programs enthusiastically, even obsessively". According to the original definition, hackers can show ingenuity and aptitude across a broad range of technological artefacts. They are challenged by exploring the configuration and mechanisms underlying of all technological systems and products (Taylor, 1999). Hacking can thus be seen as a way of exploring and manipulating things in order to understand a system's behaviour and how to overcome any limitations that the system might have (Gunkel, 2000).

The term has also been used to designate a computer *virtuoso*, a skilled computer programmer or engineer who likes challenges involving accessing and manipulating others' computers or systems (Levy, 1984; Lilley, 2002; Sterling, 1991; Turgeman-Goldschmidt, 2008) or hacking computer codes by writing programs (Ludlow, 1996). Meyer (1989) defined hackers as computer *aficionados* who break into corporate and government computer systems using their home computer and a telephone modem. Therefore the term "hacking" has been used to refer both to "creative innovation and to a form of illicit behaviour" .(Gunkel, 2000, p.799): on the one side it is applied to a person who enjoys learning the details of computer systems and how to stretch their capabilities and, on the other it is used to indicate the activity of a person who tries to gain information by manipulating others' systems using deceptive or illegal means (Steele, 1983).

Throughout the years the word "hacker" has been applied to indicate at least three distinct communities (Hannemyr, 1999). The original hackers were computer professionals who owned a certain level of craftsmanship, particularly skilled computer workers who took pride in their work and found joy in doing so (Hannemyr, 1999). Early hackers had a genuine belief in the liberating power of technology and had their own "hacker ethics" (Levy, 1984).

In the 70s, hackers became activists who believed that technology was power and computers should have been accessible to everyone as they represented the supreme manifestation of the power of technology. This second generation was characterized by the will to make computers become useful and accessible to citizens. These hackers pioneered public access terminals, computer conferencing, and personal computers (Hannemyr, 1999).

However, in the second half of the eighties the "computer underground" emerged and the noun "hackers" partially changed its meaning. To this third community, "to hack" meant to break into or sabotage a computer system, and a “hacker” was identified as the perpetrator of such activities (Hannemyr, 1999). Thus nowadays “hacking” is often used with reference to “gaining unauthorised access to a computer system with or without a further criminal motive” (Hutchings, 2013, p.2) and comes with a negative connotation.

In this thesis, a more neutral definition is adopted according to which “hacker” refers to a computer enthusiast, who enjoys learning programming languages and exploring computer systems. A hacker can be considered an expert on the subject, who mastered the art of making computers and software do much more that the original designers intended (Sukhai, 2004). This definition is closer to the original and appears less restrictive than the more recent ones, as it remains agnostic about a hacker’s intent or authorization status. Obviously, the use that hackers can make of their skills and knowledge may vary depending on personal and/or situational factors.

2.2.2 Types

Three main labels that have been frequently used in the hackers’ community and in the literature to reflect the perceived maliciousness of a hacker’s intent: white hats, black hats and grey hats (Furnell, 2002). These make reference to the colour of the hats and are borrowed from old cowboy movies, where the good guy always wore a white hat and a bad guy wore a black hat.

The types of hackers they refer to can be briefly described in the following way:

Black hats. Usually called also “crackers”, they are hackers who use their skills for illegal or malicious purposes. They break into or otherwise violate the system integrity of remote machines, with malicious intent. Having gained unauthorized access, black hat hackers destroy vital data, deny legitimate users service, and basically cause problems for their targets. A differentiation can thus be made between “hacks”, in their original meaning, and “cracks”. At the origin, a “hack” refers to “any legitimate and useful alteration or adjustment to computer hardware or software, which enables technology to be used in an innovative or unusual way” (Holt, 2010, p.215). The term “crack” is applied when “a hacker alters technology for a negative or potentially criminal application” (Holt, 2010, p.215).

White hats. These hackers use their skills to improve cybersecurity and protect against malicious hackers. The label identifies hackers who stay entirely within the law; they work to expose holes in systems with the purpose to fix flaws and improve security; they use their hacking skills for protective purposes. This type comprises security professionals with knowledge of hacking and of the hacker toolset and who use their knowledge to locate weaknesses and implement counter-measures (i.e. ethical hackers; Graves, 2010; Munson, 2009). Ethical hackers complete many of the same activities with many of the same tools as malicious hackers, or black hats. In nearly every situation, an ethical hacker should strive to act and think like a real black-hat hacker (see below). The closer the penetration test simulates a real-world attack, the more value it provides to the customer paying for the penetration testing. In general, differences between black-hat hackers and ethical hackers can be summarized in three key points:

1. Authorization: the process of obtaining approval before conducting any tests or attacks. The penetration tester and the company or individual being audited need to agree upon the scope of the test, that explicitly defines the authorized targets for the penetration tester.
2. Motivation: a malicious hacker may be driven by the desire for personal gain, revenge or fame while an ethical hacker is driven by the will to help the individual or the organization and improve their security via penetration testing, on their request. In addition, a black hat hacker may spend a significant amount of time on attacking the organization while, in most cases, penetration testing may last 1 week up to several weeks.
3. Intent: an ethical hacker's intent is to provide the individual or the organization with a realistic attack simulation so that they can improve their security through the early discovery and mitigation of vulnerabilities. Ethical hackers will keep the penetration testing findings confidential and never share sensitive information discovered during the process of penetration testing. A brief history of ethical hackers is summarized in table 2.1.

Grey hats. These are hackers who may work offensively or defensively, depending on the situation. They do not align themselves with any specific moral philosophy but rather act to achieve some specific goal (Holt, 2010). Both hackers and crackers are powerful forces on the Internet and some individuals qualify for both categories. The existence of such individuals further clouds the division between black hats and white hats (Graves, 2010).

Table 2.1 History of ethical hackers.

Table 2.1

History of ethical hackers

1964	"Tiger teams" emerge as a group of technical specialists selected for their experience, energy and imagination. One of the first teams was assigned to track down possible sources of failure in a spacecraft subsystem
1974	Te U.S. Air Force conducts one of the first ethical hacks, a security evaluation of the Multics operating system
1984	U.S. Navy Commander Richard Marcinko builds and leads a team of Navy Seals whose objective is to test naval bases' vulnerability to terrorism
1985	First issue of Phrack – an e-zine written by and for hackers
1986	The Computer Fraud and Abuse act cracks down on computer crimes. Certain ethical hacking methodologies are now considered illegal without a contractual agreement between ethical hacker and client
1992	The movie "Sneakers", about a fictional tiger team in San Francisco that becomes entwined in international intrigue, is released
1995	Daniel Farmer and Wietse Venema release SATAN (Security Administrator Tool for Analyzing Networks), a tool to help system administrators find and report networking-related security problems
1995	IBM's John Patrick coins the term "ethical hacking"
2003	The Open Web Application Security Project (OWASP) releases the OWASP Testing Guide, which includes a framework for penetration testing practices
2009	The Penetration Testing Execution Standard (PTES) launches, offering service providers a common language and scope for performing penetration tests.
2013	Worldwide enterprise security spending reaches $6.4 billion. Security executives begin to use on-demand penetration testing services for cost-effective ethical hacking.

2.3 Profiling hackers: empirical research

2.3.1 Personality traits

Before 2000, studies on hackers were typically conducted by mental health professionals on young adult males under the age of 30 charged with hacking-related offenses (Schell & Melnychuk, 2011). Towards the end of that period, in 1999, the U.S. Department of Defence commissioned a team of experts, including a clinical psychologist, a research analyst and a psychiatrist, to construct behavioural profiles of insider hackers (i.e., those who hack systems from inside corporations or agencies) based on 100 cases that occurred in previous years. In that study, Shaw, Ruby and Post (1998) found eight traits that characterise insider hackers: introversion; a history of significant family problems; an online computer dependency that is socially invalidating; ethical flexibility; loyalty to their computers; sense of entitlement; lack of empathy; being less likely to deal with high degrees of distress in a constructive manner. However, as Smith and Rupp (2002) noted, this profile is mainly based on convicted hackers and/or hackers who willingly volunteered to be interviewed. Smith and Rupp (2002) reviewed the literature on both insider and outsider hackers' profiles and found that: "Outsiders are: predominantly males, 12-30 years old, Caucasian, single and with a 12-level, pre-college education. They perform poorly in school but have an aptitude for computers and technology. They demonstrate limited social skills and are classified as being loners in terms of behaviour patterns. Nevertheless, they display a strong need to belong to a larger social group. They often come from a dysfunctional, single-parent and abusive family and often display compulsive traits, such as staying online for days on end without sleep. Insiders are: predominately introverts, usually experience social and personal frustrations and display loose ethical boundaries disregarding the notion of the word "private". They are often characterised by a lack of empathy and believe they deserve special recognition by their organisations." (p.11; Smith and Rupp, 2002).

Rogers, Smoak, and Liu (2006a) investigated the personality and motives of computer deviants (i.e. people who engage in activities such as virus writing, file changing and password guessing) using self-report instruments such as the Computer Crime Index, the Big-5 personality test, the Exploitive Manipulative Amoral Dishonesty Scale (EMAD) and the Moral Decision Making Scale (MDKS). They found that computer deviants scored lower on social moral choice and were more exploitive and manipulative than the non-computer deviants (used as comparison group). In a follow-up study, Rogers, Seigfried, and Tidke (2006b) found that the only significant variable for predicting criminal/deviant behaviour was extraversion, as those individuals self-reporting criminal computer behaviour were more introverted than those reporting no criminal/deviant computer behaviours. Lieberman (2003) surveyed 42 hackers at professional meetings with an ad hoc questionnaire and found discrepancy between hackers' responses and the mass media image regarding their limited social skills. Indeed, the respondents did not report having social anxiety or problems in social interactions.

Woo (2003) investigated 729 hackers with an online questionnaire specifically developed for the purpose of his study. Participants were recruited by posting the research advertisement in websites such as Hackerslab, Defcon and in hacking communities online. He found a relationship between an unstable self-esteem manifested in a high level of narcissism and heightened aggression in hackers. Additionally, hackers with higher level of nationalism displayed more anger in their reactions and behaviour and also showed a greater tendency to hack against the sites of states standing opposed to their nationality (Woo, 2003).

In 2002, Schell, Dodge and Moutsatsos surveyed behaviours, motivations, psychological predispositions, creative potential and decision-making styles of 216 hackers attending either the H2K conference in New York city or the DefCon 8 conference in Las Vegas. Contrary to what is reported by other authors, they found that childhood trauma or significant personal losses had been experienced by 28% of respondents. They also found a degree of multi-tasking capability among hackers attending the conference, as the respondents said they were engaged in about 3-4 hacking projects weekly. Overall, the conference attendees appear to be good stress managers, capable of multitasking, highly creative and with analytical and conceptual decision making styles (Schell et al., 2002). It has to be stressed though that these findings apply to those attendees who volunteered to complete the questionnaires distributed by the researchers at the conference.

Creativity seems also to be an important trait for hackers, as they enjoy finding new ways to penetrate systems such as with vulnerability exploitations and with social engineering (Blake, 1994; Caminada, Van de Riet, Van Zanten & Van Doorn, 1998; Mitnick, Simon & Wozniak, 2003). Empirical testing of creative potential using validated instruments has been largely absent from the research literature on hackers, but not from that on programmers (Schell et al., 2002). For example, it was shown in the past that individuals who have an interest in computing from childhood or who later choose a career in computing, are likely to be more creative and intuitive than their peers (Sitton & Chmelir, 1984). These individuals not only face life expectantly and at the expense of observation, but they are initiators and inventors (Schell et al., 2002). In general, creative people are thought to enjoy intellectual stimulation and to be mentally flexible as they solve problems by looking at them from a non-traditional, out-of-the box vantage point (Dubrin, 1995; Kreitner & Kinick, 1992).

The popular representation of hacker communities also includes stereotypical elements that may signal common personality traits (Bachmann, 2010). The first element is their need for cognitive challenges (Dalal & Sharma, 2007; Holt & Kilger, 2008; Shell & Melnychuk, 2010). Hackers long to learn about technical intricacies of systems and processes, enjoy exploring their details, and thrive on mastering the intellectual challenges involved in altering or circumventing their functions and limitations (Bachmann, 2010). The second element is their seek for thrill, that is they derive pleasure and excitement from the chase, from overcoming barriers and from gaining access to other systems (Levy, 1984; Yar, 2005). This drive may be particularly strong in black hats, who use their skills to break into systems illegally. Bachmann (2010) investigated how these personality traits may affect hackers' behaviour through the lenses of two popular criminological theories: Self-control theory (see following section 2.3 2 for more details on this perspective) and Rational Choice theory. The rational choice perspective stresses the importance that the offender understands the risks and outcomes of an action, considers the alternative and deliberately decides to take the risk (Clarke & Cornish, 2001). In light of this Bachmann was interested in whether the degree to which hackers show preference for rational decision making[4] on the one hand and for engagement in risky activities on the other influences their overall engagement in hacking activities and self-reported success as hackers. He surveyed hackers who admitted to having engaged in illicit hacking activities (specifically technical intrusions, social engineering attacks and malware distribution) at Washington D.C. ShmooCon 2008 hacker convention with an ad hoc self-report instrument. Bachmann (2010) reported that hackers: have a considerably higher need for cognition and higher risk propensity than the general public; tend to prefer rational thinking styles over intuitive approaches; demonstrate a particularly high confidence in their ability to reach optimal decisions through a rational deliberation process; prefer complex problems over simple ones and enjoy solving problems that require hard thinking more than the average person; are more prone to engage in potentially risky behaviours than members of the broader population. An individual's risk propensity influenced the number of total hacking attempts; additionally, the preference for analytic-rational thinking styles was significantly and positively correlated with the number of attacks. The higher the preference for an analytic-rational approach to thinking and the lower the

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[4] The latest version of the Rational-Experiential Inventory (REI) scale (Pacini & Epstein, 1999) was used to assess rational versus heuristic thinking styles.

risk propensity of a hacker, the more successful the hacker rated himself or herself. In summary, hackers seem to have higher need for cognitive challenges and higher risk propensity than the general public. They tend to prefer rational thinking styles over intuitive approaches and boast high confidence in their ability to reach optimal decisions through a rational deliberation process (Bachmann, 2010).

2.3.2 Motivations

Different theories have been used as a framework to explain what motivates individuals to engage in illegal hacking, and even if “there can never be a perfect accounting for all reasons theory for hacking” (Sharma, 2007, p.16). Some theories seem to be more applicable than others. One main problem is that theories have focused only on the explanation of criminal and illicit behaviour, and so they are suitable only for a subset of hackers, as not all of them are involved in criminal activities.

Extensive reviews of the motivational models of hacking were made by McBraier, (2014), Sharma (2007) and Xu, Hu and Zhang (2013). It emerges that the most easily applicable theories to criminal hacking are social learning theory (e.g. Rogers, 2001) and Gottfredson and Hirschi’s low self-control theory (e.g. Donner, Marcum, Jennigs, Higgens & Banfield, 2014).

According to social learning theory criminal behaviour is learned through an individual’s association with criminals in personal and social groups (Akers & Jennings, 2009; Sutherland, 1947). The principle of “differential association” states that individuals can learn definitions that justify or rationalize criminal behaviour through interactions with others. The principle of “differential reinforcement” would account for the probability of engaging in criminal behaviour and it refers to the balance of perceived, experienced, or anticipated reward and punishment. Skinner and Fream (1997) found that the four basic elements considered in social learning theory – differential association, imitation, definition, and reinforcement – are strong predictors of computer crimes. Accordingly, Holt, Bossler and May (2012) argued that social learning mediates the effects of race, gender, and computer skill on cyber-deviance; and those who are less likely to engage in deviant social learning process are less likely to commit deviant computer acts.

On the other hand, proponents of self-control theory (Gottfredson & Hirschi, 1990) argue that the primary difference between criminals and non-criminals lies in self-control, that is the ability to control one's emotion, behaviour and desires in face of external demands in order to function in society. Individuals with weak self-control tend to respond to tangible stimuli in the immediate environment and are more likely to be seduced by the thrill and excitement of criminal acts (Gottfredson & Hirschi, 1990). However, Bossler and Burruss (2011) found that social learning theory is a stronger predictor of hacking behaviour than weak self-control and that weak self-control contributes to hacking through social learning; indeed, those with weak self-control are more likely to participate in the social learning process and become hackers.

Routine activity theory (RAT; Cohen & Felson, 1979) was also proposed but its applicability to cybercrime is more controversial. In its original formulation, RAT posed that "criminal acts require the convergence in space and time of likely offenders, suitable targets and the absence of capable guardians" (Cohen & Felson, 1979, p. 588, emphasis in the original). Yar (2005) discussed in depth the suitability of RAT in explaining cybercrime and concluded that, because cyberspace is temporally and spatially disorganized, RAT appears to be of limited utility in this context. A more recent and extensive discussion on RAT and cybercrime was made by Leukfeld and Yar (2016), confirming that its applicability depends on the view of cybercrime as comparable to a crime which takes place in a definite space and time, as it is in the real world.

Recent empirical studies have tested one or more of these theories in a hacking context. Xu et al. (2013) conducted a case study of 6 Chinese black-hat hackers to investigate the motivations that pushed them to engage in hacking at the beginning. It emerged that their initial motivations were innocent, as they were primarily driven by fun and curiosity, and clearly an interest in computer and programming. The authors then proposed a model that combines social learning theory, low self-control theory and routine activity theory together to explain what is the trigger for engaging in criminal hacking and its subsequent evolution. According to their model, the association with other hackers, together with a shift in moral values and judgement on an individual with lack of self-control (i.e. the criminal hacker-to-be) caused the initial hacking for fun to become hacking for profit, and other personal motivations.

McBraier (2014) explored which motivations were associated with different illicit computer behaviours. The author surveyed 120 subjects, who volunteered to participate in the study advertised online, with a self-report questionnaire that probed the type of illicit behaviours they were engaged in and motivational factors. Specifically, the categories of motivations investigated, taken from the literature review were: addiction, curiosity, excitement/entertainment, money, power/status/ego, peer recognition, ideological and revenge. Dividing hackers on the basis of illicit behaviours in script kiddie, password cracker, old guard, cyberpunk, internals, he then looked for correlations between different motivations and hackers' category. He then concluded that there was a significant overlap of motives and behaviours among categories and that computer criminal behaviours are a fluid intersection of different motivational factors (McBraier, 2014).

Steinmetz (2015) proposed an original perspective on hacking as a result of a study he conducted using ethnographic field research and content analysis. He draws a parallel between hacking and craftsmanship and suggests considering hacking as a "late modern transgressive technological craft" (Steimetz, 2015, p.130). According to his study, hacking emerges as a manifestation of a mentality which comprises curiosity, problem solving orientation, systematic thinking, and creativity combined with an orientation towards breaking and creating. At the very beginning, one starts hacking moved by the intellectual challenge to solve problems; it is an autonomous exercise of trials and errors through which one can develop skills and practice over computers. The initial motivation is to challenge oneself to "move past designer expectations for systems and reinventing what can be done […] it has to have that going-outside-what-people-think-you-should-be-doing" (Steinmetz, 2015, p.139). Whether or not the intent become malicious as skills and practice increase, depends on the person himself, thus the association between hacking and criminal computer activity should not be automatic.

In summary, equating hacking to illicit intrusions, criminal and deviant behaviour is simplistic and misleading because it fails to recognize the plethora of motivational factors that trigger a person to begin hacking simply as an act of curiosity and interests on the functioning of computer systems. Moreover, cybercrime can be performed by individuals that are not part of the hacker culture. Indeed, in order to steal information from or hijack easy targets (e.g. low-security systems), it is not necessary to possess any particular skills, expertise or interest in computer systems: nowadays the internet provides tutorials and automated software to obtain the desired effect.

2.3.3 Skills and aptitudes

Although very few academic studies have specifically targeted the hacker skillset and the role of individual differences, numerous studies have looked at programmers and may offer relevant information on the hacker skillset (or at least on an important component of it).

2.3.3.1 **Cognitive skills related to programming**

Research on predictors of programming proficiency has spanned a broad range of topics in the last decades (Pears, Seidman, Eney, Kinnunen, & Malmi, 2005) and can be broadly classified into the following topics (Bergin & Reilly, 2006): (1) effect of previous academic and computer/programming experience; (2) cognitive skills; and (3) psychological factors with emphasis on perceived comfort-level on a programming course. For the purpose of this review we will focus only on research on cognitive skills related to programming.

Learning to program requires learning new reasoning skills and understanding new technical information (Canas, Bajo & Gonzalvo, 1994). Accordingly, studies have investigated the potential role of a wide range of cognitive factors on programming proficiency, including cognitive style and abstract reasoning ability. General intelligence, as measured by the General Aptitude Test Battery (Dvorak, 1956) is a strong predictor of success in an introductory computer course (Mayer, Dyck & Vilberg, 1986; Petersen & Howe, 1979). Hostetler (1983) tested the validity of the Computer Programming Aptitude Battery (described in section 2.3.4) and found that diagramming and reasoning abilities were significant predictors of the final scores in a computer introduction course. Further research also suggests that programming recruits higher cognitive abilities such as problem solving and Piaget’s formal operations (Hudak & Anderson, 1990; White & Sivitanides, 2002). Mayer et al. (1986) found that the most important predictors of a BASIC exam score were two problem solving skills: the ability to translate and solve word problems and the ability to follow procedures and directions. Austin (1987) developed a model including quantitative and algorithmic reasoning abilities, vocabulary and general abilities, self-assessed mathematical ability and measures of introverted/analytic style and extraversion level, which explained more than 60 percent of the variance in programming scores. Formal operational reasoning ability was shown to be necessary for success in procedural computer programming/logic (White & Sivitanidanes, 2002). Formal operations are the highest cognitive development level in the Piagetian theory of cognitive development (Piaget, 1972). They comprise the ability to deal with abstractions, formulate hypotheses, solve problems systematically, and engage in mental manipulations. A precondition to formal operations development is the understanding of bi-conditional reasoning, “if and only if” logic, which is the same logic used by procedural programming (White & Sivitanides, 2002). Little (1984) found that students who achieved a high score in formal operations scored higher on programming and logical thinking measures than those who were concrete operational thinkers. Additionally the ability to identify and repair programming errors appears to be significantly correlated with cognitive flexibility (measured with a task-switching test; Leinikka, Vihavainen, Lukander & Pakarinen, 2014).

Spatial ability and spatial reasoning have also been related to computer programming proficiency. Mental rotation performance has been shown to correlate significantly with programming proficiency (Cherney, 2008; Feng, Spence & Pratt, 2007; Jones & Burnett, 2008). Simon et al. (2006) conducted a study based on four different diagnostic tasks in an attempt to determine factors that might relate to early programming performance: a standard paper-folding test (a cognitive task focusing on spatial visualisation and reasoning), map sketching (a behavioural task used to assess the ability to design and sketch a simple map and to articulate decisions based on that map), searching a phone book (a behavioural task used to assess the ability to articulate a search strategy) and a standard study process questionnaire (an attitudinal task focusing on approaches to learning). They found a significant correlation between the map sketching task and the final marks. This latter finding is consistent with other studies in the literature, as Petre and Blackwell (1999) reported that expert programmers use spatial representation for programming; for example, describing a problem space as a landscape (Simon et al, 2006). Cox and Fisher (2004) showed that in developing and in understanding program code, the programmer has to locate code segments and move between them as if he or she is navigating in a virtual space.

Success in programming has also been associated to visual abilities and in particular to the ability to find patterns (Subramanian & Joshi, 1996). It is essential for programmers to rapidly recognise clichéd patterns (Soloway & Ehrlich, 1984) in problems or in the program structure and apply or extract algorithms and plans (Mancy

& Reid, 2004). Consistently, Subramanian and Joshi (1996) found that the ability to find similarities between dissimilar items and detect internal order in a number and/or letter sequence significantly predicted programming performance. According to Witkin, Moore, Goodenough and Cox (1977) the ability to recognize patterns may be related to the construct of field dependency. Witkin and Goodenough (1981) defined field dependency and independency in the following way: an individual who can easily separate an item from an organized perceptual field is called field-independent, while an individual who finds that difficult and readily accepts the dominating field or concept is described as field dependent (Mancy & Reid, 2004). That is, a field independent person will more easily extract the message from the irrelevant information, breaking the complex stimulus up into separate elements and providing a different organisation than that suggested only by salient cues in the original information (Riding & Cheema, 1991). Stevens (1983) found that field-independent students had significantly higher scores in instructional computer courses than field-dependent students. In order to measure field dependency, Witkin, Oltman, Raskin, and Karp (1971) developed the Embedded Figure Test (EFT), to measure an individual's ability to extract a simple shape from a complex visual field (pattern). A score is calculated as the number of shapes correctly identified and the student is situated along the field dependent-field independent continuum (Mancy & Reid, 2004). Mancy and Reid (2004) showed that field dependency, as measured by the EFT, has a significant positive correlation with performance in programming tasks. Students who scored well on the EFT, and thus were considered to be field-independent, achieved on average better marks in the examination. Recently Bergersen and Gustafsson (2011) found a relationship between working memory as measured by Operational Span, Symmetry Span and Reading span[5] and programming skills, assessed with a series of programming tasks; but their results indicated that the relationship was mediated by individual programming knowledge, which they had assessed with a questionnaire.

All the above mentioned cognitive skills and styles related with programming proficiency have been investigated in relation with intelligence, and are somehow

[5] In the tests participants have to memorize letters or locations while they are distracted by other tasks (i.e. math operations)

related with each other. Findings within the research on field dependence/independence have shown a statistically significant relationship between intelligence, as measured by IQ test, and EFT (Goodenough & Karp, 1961; Witkin, Dyk, Faterson, Goodenough & Karp, 1962). Specifically field-independence was associated with higher intelligence levels. Nevertheless, Rittschof (2010) pointed out that there are reasons to consider the field dependence/independence construct distinct from general intelligence, specifically they are: "(a) the particular spatial-perceptual tasks required on tests involving dis-embedding figures (e.g. HFT), (b) the moderate correlation levels typically found, (c) evidence from factor analyses and results from studies controlling for intelligence" (Rittschof , 2010, pp-101-102). The construct has also been linked with spatial ability as measured by the Block Design test, and both measures correlated with IQ (Richardson & Turner, 2000). Rittschof (2010) reviewed research on the relationship between visuo-spatial working memory and field independence and concluded that visual working memory components (Baddeley, 1986a) are involved in measures of field independence. Specifically the visuo-spatial sketchpad is responsible for the maintenance of information in visual/spatial tasks and the central executive functions are responsible for the regulation and control of the cognitive processes. Literature reports also a relationship between working memory and intelligence (Ackerman et al., 2002; Colom, Rebollo, Palacious, Juan-Espinosa, & Kyllonen, 2004; Unsworth, Heitz, Schrock, & Engle, 2005). As for mental rotation ability, research has shown unclear results; Ling, Burton, Salt and Muncer (2009) found a correlation between intelligence as measured by the Baddeley reasoning test[6] (1968b) and the MRT while other research has shown no correlation with intelligence but a correlation between mental rotation and the ability to deal with numbers (Thompson, Nuerk, Moeller, Kadosh, 2013). It might be that the Ling et al's findings can be explained in terms of an involvement of working memory in the Baddeley's reasoning task as demonstrated by Colom et al. (2004); indeed Baddeley's reasoning task can be considered a measure of intelligence but it requires the involvement of working memory systems. Support for the relationship between working memory and MRT performance was given by Kaufman (2007), who found that sex differences in mental rotation ability were mediated by spatial working memory.

[6] In the test participants have to decide whether some statements about logic relations are true or false.

2.3.4 Aptitude tests

Aptitude tests aim to provide a measure of the extent to which an individual is likely to succeed in the domain of interest, and often assume that the subject has no experience in the domain in which is being tested. The first attempt to address the relationship between programming aptitude and programming performance dated back in 1950s, when IBM developed the Programmer Aptitude Battery to help select programmer trainees. Moderate[7] significant correlations (at their best from 0.5 to 0.7) have been reported between an individual's score on such a measure and their assessed programming skill. Ever since the 1950s, global measures of programming skill, such as grade in programming training course or supervisor ranking, have served as skill assessments. These initial efforts concentrated on occupational aptitude tests in order to evaluate their utility in selecting those people most likely to have a successful career in the computer industry (Cross 1971; Mayer & Stalnaker, 1968; Wolfe, 1971). Typically, they did not address the more fundamental psychological question of how aptitude tests and performance might be related, in terms of component skills or knowledge representations mediating specific programming activities. By the 60s, aptitude tests were used by 68% of computer companies surveyed in the U.S.A. and 73% in Canada. Many of these tests "continue to be used by companies to select developers, but less intensely and as a part of a broader process of selection" (Ambrosio, da Silva Almeida, Macedo & Franco, 2014, p .3).

The most common aptitude tests, and related evidence when available, are here reviewed in order to identify the cognitive skills that are thought to be crucial from an applied point of view.

Programmer Aptitude Test (PAT). It is a one-hour test in three parts: In part I the participant is asked to identify the next number in a series (10 min); in part II the participant is asked to identify analogies represented in figures (20 min); in part III the

[7] The correlation coefficient is an indicator of the strength of a relationship between variables and can be interpreted also as an effect size. Values of ±.1 represent a small effect, values of ±.3 represent a medium effect, and values of ±.5 represent a large effect (Field, 2009, p.170)

participant is asked to solve arithmetic problems (30 min). Part I consists of 26 problems. For each problem six numbers are given and the numbers in each series follow a certain rule. For each series of numbers, the rule must be discovered and applied to it in order to complete the series. Part II consists of 40 problems in which three figures are given (A,B,C). The first two are related in some ways, and the examinee has to find the rule by which A is changed to make B, in order to determine how C should be changed. Part III is made of 20 problems regarding arithmetical reasoning. At the end, examinees are included in one of four evaluation levels: score of 69 and above – excellent, score between 57 and 68 – good, score between 45 and 56 – fair, score of 44 or below – poor (Reinstedt, 1967). In the 60s, the Electronics Personnel Research Group at the University of Southern California undertook a research program to develop objective criteria for the evaluation of Navy computer personnel on the job and predictor tests for the selection of programmer trainees. To address the relationship between aptitude tests and programmer performance, they gave a battery composed by the PAT and their *ad hoc* Test of Sequential Instruction[8] (TSI; Reinstedt, 1967) to 534 programmers. Results indicated that both tests had high correlations with supervisors' rankings. More specifically, programming performance correlated with scores on aptitude tests which require discovering logical relationship or manipulating symbols (Berger & Wilson, 1966).

In a validation study of the PAT, Mc Namara and Huges (1961) tested 245 students in programming classes at IBM and found a product-moment correlation of .50 between PAT scores and final grades. Furthermore, they investigated the relation between job performance (as measured by the managers'ratings) and PAT scores on 52 programmers at IBM and found a correlation of .36 ($p<.05$). Biamonte (1964) administered the PAT to 106 students of a programming course at New York University and also found that PAT yielded a moderate correlation with grade point average, thus confirming its predictive value (McNamara, 1967). However, Gotterer and Stalnaker (1964) administered the PAT to students enrolled in a computer course at the Georgia

[8] The TSI was a 20 minutes test in which participants were given with a sheet with a series of instruction, each word had a code letter and a number combination beneath it. The instructions given were for example to circle the code combination of the first occurrence of the word "code", or to circle the code letters of all the words beginning with "w". Each line had a different instruction and participants had to understand and change the rule according to which the test had to be done.

Institute of Technology and found that PAT scores were not predictive of either the training grade or the students' self-evaluation of training success. Mazlack (1980) also concluded that future programming skill is not predictable by the PAT. Butcher and Muth (1985) tested the validity of PAT on 63 students enrolled in a FORTRAN programming course. They reported that the simple correlation between total PAT score and course grade would only explain about 11 percent of the variance in course grade (Butcher & Muth, 1985).

Nowadays IBM uses an online version of the test, called IPAT, it is a timed test (allowing 2.15 minutes for each question) that is heavily based on numerical skills and consists of three parts: a) numerical series, in which subjects are asked to identify patterns and find the missing number; b) numerical reasoning, with 20 mathematical questions; c) mathematical problems to be solved.

Aptitude Assessment Battery Programming (AABP). Developed in 1968 by Wolfe for Walden Personnel Testing & Training Inc., it is based on tasks that simulate daily work and assess: logical reasoning, ability to interpret complex specifications, documentation and annotation skills, problem solving skills, accuracy, attention to detail, speed, concentration and ability to follow instructions accurately. Throughout the years, and with the progress of programming aptitude testing, new features were added to the battery. The most recent additions include a set of tasks that measure logical ability, interpretation of specifications, attention to detail, accuracy and reasoning with symbols and this updated version has been renamed Programmer Analyst Aptitude Test.

The Computer Programmer Aptitude Battery (CPAB). Published by Vangent Inc., it is a timed battery of tests that seeks to determine individual aptitude for computer programmer or system analyst jobs and is composed of five subtests. These assess aptitudes for verbal processing (i.e., understanding the vocabulary used in mathematics, management and system engineering literature), mathematical reasoning (i.e., translating ideas and operations from textual notation into mathematical notation), letter series reasoning (i.e., using abstract reasoning to find patterns in given letter series), number ability (i.e., analysing number problems), and flow chart diagramming (i.e., finding solutions to a logical sequence using diagrams). The CPAB comes in a short and in a long version; the former contains only those parts related to Reasoning and Diagramming that make up the long version, and which have been shown to be those that best predict the performance of programmers.

The Berger battery. A set of proficiency and aptitude tests marketed by Psychometrics Inc., it comprises tests on several programming languages, and the B-APT (for people with no programming experience) which aims to identify candidates for training. It consists of thirty questions that must be answered in 1h15’ and uses a hypothetical language that candidates must use to write small programs.

Computer Aptitude, Literacy and Interest Profile Test (CALIP). It was developed by Poplin, Drew and Gable (1984) “to identify talented individuals who might want to specialize in a computer-related career, apart from previous experience and complex verbal skills (e.g., reading comprehension)” (Subramanian & Joshi, 1996, p. 33). As research indicate that programming success may depend on an individual’s ability to organize problems and their solutions into conceptual categories (Mayer, 1979; Soloway, 1986), CALIP includes a broad sampling of task formats related to computer abilities, such as logical, sequential, spatial and quantitative problems (Subramanian & Joshi, 1996). It comprises 5 subtests based on the premise that pattern recognition predicts success in programming and is preceded by a mental inventory of familiar patterns (Brown, Sherbenou & Johnsen, 1982). These subtests are: the estimation subtest, the graphics pattern subtest, the logical structures sub-test, the series sub-test and the interest subtest. The estimation sub-test consists of 24 diagrams where the person is asked to determine the number of blackened squares. The imposition of a two-minute time limit forces the individual to choose between answering fewer questions by counting the blocks or answering more questions by estimating. The graphic pattern sub-test includes 20 questions and is designed to be a language-free test of problem-solving ability. Each question contains a set of figures in which some or part of the figure is missing. By using implicit rules of patterning, the person is expected to select the correct figure following the pattern. The logical structure sub-test measures the ability of a person to find similarities between apparently dissimilar pairs or groups of items. Its 20 items are numbers, letters or words which typically proceed with an implicit pattern. The series sub-test requires the person to complete a number and/or letter sequence for 24 items. In addition to encouraging lateral thinking, as the previous sub-test does, this sub-test also rewards the person who can detect internal and highly structured order. The interest sub-test attempts to measure factors related to long-term motivation and direction of effort but does not measure competence in programming.

The 20 items are related to four categories of intellectual endeavour: people-oriented, things-oriented, numeric and qualitative/emotional (Subramanian & Joshi, 1996). Subramanian and Joshi (1996) investigated the predictive efficacy of the CALIP in relation to programming performance among students from high school and from graduate school. The data were analysed using multiple regression models where the dependent variable was a participant's weighed mean score on programs and exams and the independent variables were the scores on each of the CALIP sub-tests. For the high school sample the independent variables explained 31% of the variance in the dependent variable. Their model was statistically significant and the series sub-test was positively and significantly associated with the dependent variable, while the other sub-tests were not. Elimination of all the independent variables except for the series sub-test greatly increased the statistical significance of the model, and the series sub-tests by itself still explained 29% of the variance in programming performance. However, in the graduate students sample, the model was not significant. An examination of the independent variables revealed that the logical structures sub-test was the only one significantly and positively associated with the dependent variable, while the others were not. Once again, elimination of the nonsignificant independent variables caused the model to become statistically significant. Based on this evidence, the potential validity of the CALIP, therefore seems to lie in the series sub-test and, at a later age, in the logical structure sub-tests rather than in the full battery. The series sub-test probes an individual's ability to detect an internal order in a set of numbers or letters; this may be related to procedural programming, which requires programmers to specify a sequence of steps for solving a problem, implying the previous detection of an internal order within the problem (Subramanian and Joshi, 1996).The logical structures sub-test probes an individual's ability to relate dissimilar objects, and requires creative and divergent thinking.

Aptitude tests have been widely used for recruiting programmers (Mayer & Stalnaker, 1968; Pea & Kurland, 1983). However, their overall predictive power seems uncertain. Overall, studies using multiple linear regression models (Butcher & Muth, 1985; Deckro & Woundenberg, 1977; Konvalina, Stephens & Wileman, 1983) reported standardized R-square values between .11 and .40 , showing the "models' poor goodness of fit and inability to account for even half the total variation in class performance" (Evans & Simkin, 1989, p. 1322).. Research in the field of aptitude testing has shown that broad-based tests that assess mathematical, logical skills and mental organization may be good predictors of success in programming (McKeithen & Reitman, 1981; Subramanian & Joshi, 1996). Wolfe (1971) discussed the limitations of programming aptitude tests, arguing that the use of multiple-choice questions, the test-wiseness of the college graduate group, and the inclusion of questions with mathematical information tend to diminish the effectiveness of such tests as predictors of success in programming. On the other hand, Tukiainen and Monkkonen (2002) conducted an empirical study to evaluate whether the programming aptitude of Finnish polytechnic students can be predicted using the results of scholastic aptitude tests that measure one's ability to make logical conclusion, learning ability and verbal ability. Verbal ability was tested by having students follow a given set of instructions, logical ability was tested through tasks in which they had to handle relations between different words, while learning ability was tested through tasks where they had to convert words into numbers according to a given set of instructions as fast as possible. In order to measure programming aptitude, Tukiainen and Monkkonen (2002) used the PAT (Huoman, 1986). Results showed a significant correlation between the PAT and the final exam score and they concluded that the two measures may tap on the same students' abilities.

In conclusion, several factors that relate with programming proficiency have been identified in the aptitude testing literature, such as mathematical reasoning, logical reasoning and the ability to find rules and patterns in strings of symbols. However, a comprehensive model of the factors that affect programming ability has not been identified yet (ElGamal, 2013).

2.3.5 Differences between hackers and programmers

The ability to program computers is integral to the original definition of a hacker; programming is a fundamental prerequisite for many hacking techniques as computers run on programs that can potentially be modified or exploited. The single best thing one can do to become a hacker is to learn programming computers. Therefore, the vast literature on programmers' skills and aptitudes just reviewed is relevant for the purpose of this thesis. However, at least when learning occurs within an official educational path, hackers and programmers typically differ in their training. For example, several topics in the educational curriculum of a typical hacker are either missing from computer science courses or presented in a different fashion. According to Bratus (2007), hackers tend to treat special and border cases of standards as essential; they insist on understanding the implementation of the underlying Application Programming Interface (API[9]) and exploring it to confirm the claims of documentation; they second-guess the implementer's logic, reflect and explore the effects of deviating from the path of standard tutorials; and they insist on tools for examining the full state of the system across interface layers and for modifying these states bypassing the standard development API. On the other hand, traditional Computer Science students are implicitly trained to follow the prescribed patterns, often without systematic exploration of the effects of deviating from them (Bratus, 2007).

Conti (2006) also argues that hackers possess a more intellectually curious and scientifically open-minded attitude than traditional programmers. Though they are largely self- and peer-taught, in many ways their expertise and problem solving skills exceed the academic ones. Indeed, in typical academic settings there exist time constraints in curricula and different topics need to be covered in a limited amount of time; moreover, students are likely to adopt a time-efficient "copy-and-paste" approach to the prescribed solution templates without additional exploration (Bratus, 2007, p.2). Self- taught hackers spend a huge amount of time learning from scratch and are not subject to the academic restrictions in terms of time and breath of topics learnt.

The partly different training of hackers and programmers reflects the different approach and attitude towards computers that is required by their future roles. Programme developers do need to be creative but are also often rewarded "for sticking to tried-and-tested recipes of making things work and avoiding non-standard and non-portable features […]. In short, developers *may tend to* intentionally confine themselves to working within narrowed models of computing environments, for better productivity or compatibility, whereas in reality such confines do not exist or can be bent by the attacker" (Bratus, 2007, p. 9; emphasis added).

[9] APi is a set of routines, tools and protocols for building software application. It is a set of standardized requests that software sends to another software in order to make this latter do some things for it. In essence, a program's API defines the proper way for a developer to request services from a program.

According to Steinmetz (2015), the hacker mentality builds on five components: curiosity, problem solving, systematic and technical thinking, thinking in a creative and unconventional manner, and orientation towards breaking and re-creating. Curiosity seems one key feature of being a hacker, and is also indicative of hacking's relationship to craftwork as all the efforts to do good-quality work depend on curiosity about the material at hand (Sennett, 2008). The problem-solving orientation emerges in many of the social elements of hacker culture (Steinmetz, 2015) as for example the typical 'Capture the Flag' competitions that challenge participants at hacking conferences (e.g. DefCon capture the flag competition). Systematic and technical thinking refers to the ability to approach a problem in a manner which is efficient and systematic (Steinmetz, 2015). Thinking in a creative and unconventional manner, also referred to as 'thinking out of the box' is essential as is it not enough to approach things in a logical and critical capacity, but it is necessary to be willing to think unorthodoxly and look for different ways to solve a problem. These elements combined together – problem-solving orientation, systematic and technical thinking and thinking out of the box – form what Sennett (2008) calls "practical creativity". The fifth and last element of the hacker mentality according to Steinmetz (2015) is the orientation towards breaking and re-creating, that is thinking about things in terms of their capacity to be taken apart, broken, fixed and reconfigured. This dynamic repair (Sennett, 2008) is a key feature of the hacking culture and involves changing an object's initial form or function once it is reassembled. Finally, it should be mentioned that Steinmetz (2015) used overt participant observation and semi-structured interviews, and the portrait he offers is built heavily on the hackers' own words. One might question whether the above mentioned components of the hackers' mentality can apply also to programmers. On the one hand it is plausible that thinking in an unconventional and creative way together with an attitude towards breaking and re-creating might be characteristics of hackers as they usually try to break security previously implemented by programmers and to reconfigure systems already developed in a different way. On the other hand, it is plausible that the systematic thinking and the problem solving skills might be shared also by programmers. What is it clear though is that the difference performed are built according to a programming knowledge that needs to be mastered in order to be able to violate them, fix their bugs or alter their functioning.

2.4 Conclusions

The main question discussed in this chapter was whether there exist some specific cognitive skills related to hacking expertise, and if so, whether and how they have been investigated. Research evidence on hackers' motivations and psychological traits was discussed and the lack of studies specifically designed to target cognitive abilities involved in hacking expertise was highlighted. On the basis that programmers' skills must be possessed by hackers, the focus shifted on research on programming skills. Differences and similarities between hackers and programmers were also discussed. They might share some skills, as programming knowledge is a prerequisite for the development of hacking expertise; but they are also characterized by some peculiar differences; these differences lie mainly in the mentality, and in the aptitude and approach towards computers. Programming proficiency is significantly related to certain tasks of spatial ability, spatial attention and working memory. Interestingly, performance in similar tasks is found to be superior in individuals with high functioning autism and Asperger syndrome. These skills have also been related to characteristic traits such as systemizing and attention to detail in the general population. In light of this, in the following chapter a new theoretical model of hacking is proposed, whereby systemizing may be related to hacking skills through attention to detail and the ability to analyse rules and patterns.

3 SYSTEMIZING, HACKING AND THE ASSOCIATION BETWEEN THEM

3.1 Introduction

The association between autistic traits and interests and talents in programming is not a new one. In a classic Wired article, Silberman (2001) discusses the presence of autistic and Asperger's traits in the Silicon Valley, calling it "The Geek syndrome". He writes: "It's a familiar joke in the industry that many of the hard-core programmers in IT strongholds like Intel, Adobe, and Silicon Graphics – coming to work early, leaving late, sucking down Big Gulps in their cubicles while they code for hours – are residing somewhere in Asperger's domain" (https://www.wired.com/2001/12/aspergers/). Given that autistic people have difficulties in multi-tasking, face-to-face interaction and with chaotic environments and situations; working in front of a computer screen allows them to put something between them and the rest of the reality (Silberman, 2001).

3.2 Overview of autistic spectrum conditions (ASC)

Research has shown that within the subclinical population, autistic traits happen to be more highly expressed in individuals with a scientific background, and evidence suggests a link between autism spectrum conditions and occupations/skills in maths, physics and engineering (Baron-Cohen, Wheelwright, Stone & Rutheford, 1999; Baron-Cohen, Wheelwright, Skinner, Martin & Clubley, 2001). Recently, the media highlighted that some renowned hackers – e.g. Gary McKinnon and Kevin Mitnick – suffer from an autistic condition (http://www.telegraph.co.uk/news/worldnews/northamerica/usa/4320901/Gary-McKinnon-profile-Autistic-hacker-who-started-writing-computer-programs-at-14.html; http://www.zdnet.com/article/ghost-in-the-wires-the-kevin-mitnick-interview). The link between computer programmers, hackers and autistic traits is supported by the findings that some cognitive skills that are related to programming proficiency are also known to be related with autism spectrum conditions and subclinical autistic traits. Before discussing this, a brief account of autistic spectrum disorder is given in the following paragraphs.

The symptoms of autistic spectrum disorders appear to be distributed on a continuum according to the degree or their severity, and this continuum extends into the neurotypical population without any clear separation between the latter and the clinically diagnosed individuals (Happe, Ronald, & Plomin, 2006; Koolschijn, Geurts, van der Leij & Scholte, 2015; Richmond, Thorpe, Berryhill, Klugman & Holson, 2013). Autistic spectrum condition (generally referred to as ASC) comprises at least two major subgroups: classic autism and Asperger Syndrome (AS).

Asperger Syndrome is often referred to as High Functioning Autism, although nowadays they are diagnosed as two different conditions within the Autistic Spectrum. The reason why they are often put together is that individuals with diagnosis of AS or HFA have average or above average intelligence while they both have difficulties in social interactions and communication. AS and HFA appear to be very similar, and this is at the basis of the debate on whether they might still be considered two different conditions; nevertheless a difference is that while for a diagnosis of HFA it is necessary the presence of a delay in language development in the early childhood, in AS there is no such a delay. Within the ASC there is a huge amount of variations, however common characteristics, shared by AS and HFA and other autistic conditions, are difficulties in social interactions and obsessional interests (Baron-Cohen, 2008).

3.3 Cognitive models of ASC

Different theories have been developed to explain the findings within cognitive research on autism; below the main theories are briefly discussed.

3.3.1 Executive dysfunction theory

The term executive function is an umbrella term under which fall a set of processes necessary for self-regulation and for managing one’s behaviour towards a goal. Evidence of impairment on executive functions in ASC individuals has been shown in performance on several neuropsychological tests (see Kleinhans, Akshoomoff & Delis, 2005 for a review). Research in this area have focused mainly on three specific executive dysfunctions – mental flexibility, planning and inhibition (Hill & Frith, 2003). As for the reduced cognitive flexibility, cognitive rigidity is thought to reflect repetitive, stereotyped and restricted patterns of behaviour in lower functioning ASC individuals, explained as a result of a failure of inhibition (Turner, 1997). Planning impairments have been studied (Ozonoff & Jenson, 1999) and used to explain the inability to monitor, evaluate and re-update a sequence of events. Findings of an impaired inhibition in ASC compared to the general population are controversial, as in typical inhibition tasks such as the Stroop test[10], ASC performed as well as controls (Ozonoff, 1997). Several problems with the executive dysfunction account of ASC have been raised (Lawson, 2004): the model cannot fully account for some characteristics of the ASC such as the presence of "islets of abilities" in some domains; it does not explain why in ASC there are social impairments that are absent in other conditions characterized by executive dysfunctions (i.e. Tourette syndrome); and it fails to explain why, if ASC have impaired inhibition, their performance in tasks as the Stroop test is as good as that of neurotypical individuals.

3.3.2 Weak Central Coherence theory (WCC)

Frith (1989) developed the notion of central coherence defining it as the tendency shown by normal developed adults of processing information globally, to combine incoming information in higher-level meaning, usually at the expense of local details (Frith, 2003). According to the WCC theory of autism, called also "detailed-focused cognitive style" theory (Frith, 2003; Happe, 1996, Happe & Frith, 2006; Happe' & Vital, 2009) ASC people have a strong local processing bias due to which they tend to focus on small details rather than seeing things as a whole. Their ability to infer higher level of configurations and meanings is impaired as they have the tendency to examine only local aspects of events. Evidence of this can be seen in performance on the EFT (Witkin et al., 1971), a test in which subjects are presented with a complex figure and they have to find a simple shape embedded in the complex one and in the Block Design test (Kochs, 1923), a test in which 16 coloured cubes are given to participants and the task is to reproduce with the cubes some patterns that are shown in a series of cards. ASC people perform better and quicker compared with normal and IQ-matched control groups (Happe' & Frith, 2006; Shah & Frith, 1983; Joliffe & Baron-Cohen, 1997). This detail-focused processing bias was used to explain not only weaknesses but also strengths of ASC, such as talents in savant domains showed by

[10] In this task participants are presented with coloured words, such as blue, red, or green. The task is to name the color of the ink the words are printed in, while fully ignoring the actual word meaning. Performance is better when the colour and the meaning are the same, and is worse when the colour and the meaning are different, because it is needed to suppress the effect of the meaning and focus only on the colour.

ASC individuals; for example it was argued that the ability to attend details might help in realizing realistic-looking drawings or to have an absolute pitch in the music domain (Happe & Vital, 2009). According to the most recent formulation of this theory, weak central coherence is not just or necessarily a lack in the ability of extracting global meaning, but is also an outcome of superiority in local processing (Happe' & Frith, 2006), something that appears to be a processing bias rather than an overwhelming deficit in global processing. Indeed, there is evidence that when ASC individuals are explicitly instructed to attend to the global information in a selective attention task, the Navon task (Navon, 1977), such bias may be overcome (Plaisted, Swettenham & Rees, 1999). Local processing style could thus be considered as one end of a continuum of cognitive styles rather than the result of an impairment. Neurotypical individuals can show themselves a strong local processing characterized by excellent attention to detail. Individual differences and sex differences in the normal population have been shown, for example in the EFT (Happe' & Frith, 2006). It has been questioned whether this local processing bias is linked with other facets of ASC such as poor social skills. Such relationship has been investigated by different authors using a variety of assessment instruments and, overall, the findings are unclear: some studies have demonstrated no relationship between central coherence and social skills while some other have found that the two are related (see Russell-Smith, Maybery, Bayliss, Sng, 2012 for a review of studies). Russell-Smith et al. (2012) investigated specifically the relationship between EFT performance (mean response times) and two AQ subscales, "attention to detail" and "social skills" (Baron-Cohen, Wheelwright, Skinner, Martin & Chubley, 2001). They tested a sample of 752 non-clinical undergraduate students, dividing them in groups according to scores on the two subscales of AQ (low social skills-low attention to detail, high social skills – low attention to detail; low social skills-high attention to detail; high social skills-high attention to detail). They found a significant main effect of social difficulties (high scores on the social skills subscale) on mean EFT response time, but no effect of attention to detail. The authors suggested that EFT performance may be specifically related to social difficulties and so that the local processing bias might be modulated by social impairment (Russell-Smith et al., 2012). The findings were explained in terms of a deficit in the ability to integrate or interpret information, which might cause problems in social situations (Russell-Smith et al., 2012). This however, is at odds with other studies that found no relation between self-reported attention to detail and social skills as measured by the AQ in a large sample of the neurotypical population (Rusconi et al., 2015) and a positive correlation between visual acuity or the attention to detail subscale of the AQ and performance in the EFT but no correlation between the social skills subscale and performance in the EFT (Brosnan, Gwilliam, & Walker, 2012; Rusconi, 2014). It is also at odds with the proposal that full-blown ASC may originate from the co-occurrence of deficits in a series of loosely connected abilities (Happé, Ronald, & Plomin, 2006).

3.3.3 Extreme Male Brain theory

This approach emerged in the early 2000s from within the Theory of Mind deficit account of ASC originally proposed by Baron-Cohen, Leslie and Frith (1985). The EMB was developed as an extension of the Empathizing-Systemizing theory of sex differences (E-S; Baron-Cohen, 2002). Central to this theory are two psychological constructs: empathising and systemizing. Empathizing is "the drive to identify another person's emotions and thoughts and to respond to these with an appropriate emotion" (Baron-Cohen, 2002, p. 248). In order to empathise one has to infer others' thoughts or feelings, understand them, and react emotionally in a spontaneous way. Empathizing is extremely useful to understand and predict social situations. Systemizing is the drive to analyse the rules underlying a system, in order to predict its behaviour, more specifically, it is the drive to analyse, understand, predict, control and construct rule-based systems (Baron-Cohen, 2002; Baron-Cohen et al., 2003; Billington et al., 2008). The E-S theory proposes that in the general population there are five broad brain types distributed on the empathizing – systemizing continuum: (1) Female brain, in which empathizing prevails over systemizing; (2) Male brain, in which systemizing prevails over empathizing; (3) Balanced brain, where both dimensions are equally present; (4) Extreme male brain, in which systemizing is highly expressed and there is a lack of empathizing, (5); Extreme female brain, in which empathizing is highly developed but systemizing is lacking. The E-S theory thus argues that it is the discrepancy between empathizing and systemizing that determines the probability that an individual develop an ASC (Baron-Cohen, 2010). Its value is that it is able to explain both the impaired social communication (low empathy) and the repetitive behaviours and the resistance to change (high systemizing), as the sameness makes easy to systemize.

The theory was developed from empirical evidence suggesting a systematic difference between sexes in the ability to empathise and systemize with females showing more empathizing skills and males performing better in the systemizing domain. According to this theory, people with ASC have high systemizing ability but are impaired in empathizing (Baron-Cohen, Wheelwright, Griffin, Lawson, & Hill, 2002). Evidence supporting this theory shows that female performance on tests that measure empathizing abilities (i.e. Reading the Mind in the Eyes test, Faux Pas Test) is better than male performance, while performance of people with ASC is worse than normal males' performance (Baron-Cohen et al., 1997, 1999a). On the other hand, performance in tests that measure systemizing ability such as the EFT shows that males outperform females and ASC people scored even higher than normal males. This difference mirrors the scores on the Autistic Quotient questionnaire (AQ; Baron-Cohen, Wheelwright, Skinner, Martin & Clubley, 2001) – a self-report measure of autistic traits –in the general population and in clinical groups, where males score higher than females and ASC people score even higher than normal males. The Extreme Male brain theory was then developed as an extension of the E-S theory of sex differences and argues that ASCs represent one end of a distributed pattern of cognitive differences within the general population, specifically represents an extreme of the typical male profile (Baron-Cohen. 2002; Lawson, Baron-Cohen & Wheelwright, 2004). The theory at its core argues that the extreme male brain, characterized by hyper-systemizing, is more prevalent in males than in females and vice versa, that the extreme female brain, characterized by hyper-empathizing, is more prevalent in females; the ASC lies in the extreme of the continuum of the male brain. Baron-Cohen, Knickmeyer and Belmonte (2005) investigated the EMB at the neuroanatomical level and found that the brain differences between males and females are exaggerated in ASC, i.e. parts that are bigger in males than females are even bigger in ASC, and vice versa parts that are smaller in males compared to females are even smaller in ASC; moreover ASC have usually larger brains than males, and males have larger brains than females. Another argument proposed by Baron-Cohen in support of the idea that males are more systemizers than females is that the exposure of the foetus to high levels of prenatal testosterone results in a different development of the brain hemispheres. Specifically, it is argued that due to the high levels of testosterone, the right hemisphere results more developed than the left hemisphere, i.e. it is bigger and functions better than the right one (Bryden, McManus & Bulman-Fleming, 1994).

Criticisms to this theory have arisen. Research investigated whether the differences between the sexes in empathizing and systemizing is innate. Connellan, Baron-Cohen, Wheelwright, Batki and Ahluwalia (2000) studied a sample of 102 one-day-old neonates and found that females spent most time looking at faces while males spent more time looking at a mobile. While authors argued that this finding support the theory that the sex differences are innate, some critics (Nash & Grossi, 2007) have argued that the time spent looking at a social stimulus vs. a mechanical stimulus does not allow to foresee if the preference would be maintained also later in life. Supporting this latter statement, other authors (Newcombe, 2002; Wynn, 1992) found no sex differences in systemizing abilities (e.g. spatial reasoning ability) in children. Vigil (2008) recently suggested that it has to be taken into account the importance of the parental and peer influence in affecting systemizing and empathizing abilities. Evidence against the hypothesis of different size of brain regions was also found; some research found no differences in the right or eft hemisphere in males and females, some other research found poor systemizing abilities in females exposed to testosterone (Chapman, Baron-Cohen, Auyeung, Knickmeyer, Taylor & Hackett, 2006; Witelson, Beresh & Kigar, 2005).

For the purpose of this thesis, I will not pursue an exhaustive evaluation the EMB but focus more closely on the concept of systemizing proposed therein, and discuss the possibility of a link between systemizing and hacking skills.

3.4 Systemizing

Systems can be of several types – technical, natural, abstract, social, organisable, motoric – but they all share the same underlying processes represented by a tripartite structure: input - operation - output. Dealing with these systems means examining relationships between components and correlations between events in order to detect any underlying rules, in other words, to identify regularities (Lawson et al., 2004). Systemizing involves five phases:

1. *Analysis*: single observations of input and output are recorded in a standardized manner.

2. *Operation*: an operation is performed on the input and the change to the output is noted.

3. *Repetition*: the same operation is repeated over and over again, to test whether the same pattern between input and output is obtained.

4. *Law derivation*: a law is formulated of the form “if X (operation) occurs, A (input) changes to B.”

5. *Confirmation/disconfirmation*: if the same pattern of input-operation-output holds true for all instances, the law is retained; otherwise phases 2-5 are repeated.

Systemizing works for phenomena that are lawful and deterministic and it is a useful and powerful way to predict and control the behaviour of a system (Baron-Cohen et al., 2003; Ling, Burton, Salt, Muncer, 2009). To systemize, one uses “if-then” correlation rules, which means that the person attends to a detail or parameter of the system and observes how this varies (Baron-Cohen, 2008). It can be a passive or an active process, in the latter case a person actively (systematically) notes the effects of operating on one single input in terms of its effects elsewhere in the system (the output): if I do x, a changes to b; if z occurs, p changes to q. Crucial to systemizing is thus an exact eye for detail (Baron-Cohen, 2002, 2008).

Systemizing is highly expressed both in AS and classic autism (Baron-Cohen, 2008). For example, Baron-Cohen (2008) reported that people with ASC have an increased rate of savant skills, often in lawful systems such as calendars, calculation, or train timetables (Hermelin, 2002); they score higher than average on the Systemizing Quotient (SQ; Baron-Cohen, Richler, Bisarya, Gurunathan & Wheelwright, 2003), on tests of folk physics (Baron-Cohen et al, 2001; Joliffe & Baron-Cohen, 1997; Lawson, Baron-Cohen & Wheelwright, 2004; Shah & Frith, 1983) and on test of attention to detail (O’Riordan, Plaisted, Driver & Baron-Cohen, 2001). They can achieve high levels of expertise in domains such as mathematics, physics, or computer science, which deal with extremely lawful and predictable systems. Studies have found that individuals with a high systemizing style, such as scientists and mathematicians, perform better on perceptual tasks of field independence (Billington, Baron-Cohen & Bohr, 2008). Indeed Baron-Cohen, Wheelwright, Skinner, Martin, and Clubley (2001) showed that science students (computer science, maths, engineering, biology and physics) score higher on the AQ than humanities students and social science students. Moreover, within science students, those in such areas as maths, computer science and engineering scored higher than students in more human or life-centred sciences such as medicine and biology.

Morsanyi and colleagues (Morsanyi, Primi, Handley, Chiesi, & Galli, 2012) tested whether SQ scores may be useful in recognizing individual differences in attitudes and interest in science fields, especially mathematics and engineering, which are the most often cited examples for sciences involving high levels of systemizing (Baron-Cohen et al., 2003). They used the shortened version of the SQ (Ling et al., 2009), together with self-reported measures of attitudes towards mathematics and statistics, the Bennett Mechanical Comprehension Test Bennett, 1969), and a short form of the Raven Advances Progressive Matrices (Arthur & Day, 1994). The authors found that SQ was significantly correlated with mechanical reasoning ($r=.29$, $p<.01$) and that both the SQ ($\beta=.21$, $p<.05$) and the Raven scores ($\beta= .36$, $p<.001$) were significant predictors of mechanical reasoning performance ($R^2= .16$, $p<.001$).

As previously mentioned, males are thought to have a stronger drive to systemize than females (Baron-Cohen, 2008). Boys are more interested in activities that require systemizing, certain occupations focused on creating systems are largely male, academic degrees such as maths, physics and engineering all require high systemizing and are largely male; men score higher in tasks that require dealing with 3-D structures (Baron-Cohen, 2008). To support this, sex differences have been demonstrated within systemizing domains, as males show higher scores on self-reported measures of systemizing such as the SQ and SQ-R (Baron-Cohen et al., 2003; Billington et al., 2008; Wheelwright et al., 2006) as well as in tasks involving systemizing skills – i.e. predicting physical systems, constructing 3-D models and geospatial navigation (Baron-Cohen, 2008). As discussed before, the role of parental and peer influence and genetics in explaining this sex differences is still argument of debate.

3.4.1 Measures of systemizing

According to Baron-Cohen (2008), systemizing can be assessed by means of different instruments. The most common measures of systemizing are the Systemizing Quotient questionnaire and the Systemizing Quotient-revised. Another questionnaire is the Physical Prediction Questionnaire that requires participants to understand and predict physical transformation about engineering problems.

Other behavioural measures are considered to assess systemizing abilities and they are: constructing 3-D structures; the Embedded Figure test because it taps attention to detail which is a feature of systemizing; the Mental Rotation test because it requires to understand a transformation rule and to apply it and Reading Maps test because it involves the ability to transform 3-D representations in 2-D representations Baron-Cohen (2008).

For the purpose of the present thesis, it was chosen to assess systemizing using the SQ and the SQ-r described below. The choice was motivated by the fact that they are the most common measures used in the literature and thus it was possible to compare results obtained with previous findings. Moreover, there exists a validated Italian translation of the SQ (see https://www.autismresearchcentre.com/arc_tests) and this allowed to administer the experiment to the Italian population in Study 2 using the same instrument of Study 3 and thus allowing comparison between the two studies. The choice to use Italian participants was motivated by the need to recruit as many participants as possible and my network of contacts was larger in Italy. In Study 3 the original English version of the SQ was used as participants were English speakers.

Systemizing Quotient

The SQ (Baron-Cohen et al., 2003) comprises 60 items, 40 of which are aimed to assess systemizing and 20 of which are filler items. It uses a 4 point Likert scale on which participants are asked to indicate the degree to which they agree with some statements. The 4 choices are: "strongly agree", "slightly agree", "slightly disagree", "strongly disagree". In order to avoid response bias, half of the items are reverse scored "Strongly agree" scores 2 points and "slightly agree" scores 1 point on the following items: 1, 4, 5, 7, 13, 15, 19, 20, 25, 29, 30, 33, 34, 37, 41, 44, 48, 49, 53, 55. "Strongly disagree" scores 2 points and "slightly disagree" scores 1 point on the following items: 6, 11, 12, 18, 23, 24, 26, 28, 31, 32, 35, 38, 40, 42, 43, 45, 51, 56, 57, and 60. In both cases the other two options score 0. The 20 filler items - items 2, 3, 8, 9, 10, 14,16, 17, 21, 22, 27, 36, 39, 46, 47, 50, 52, 54, 58, 59 – are not scored and do not contribute to the total score. The total score can theoretically range from 0 to 80. SQ has usually been considered a unifactorial construct although factor analyses showed that a model with all items loading on to one factor is not a good fit to the data. The best model proposed in literature is a four factor model based on 18 items of the SQ (Ling et al., 2009).The model was developed from an initial version of 25 items proposed by Wakabayashi et al. (2006) and comprised items that load into four different factors: technicity, topography, structure, DIY. (see table 3.1). A detailed description of analyses on the psychometric properties of the SQ is provided in the box 3.1.

Table 3.1 Four factors structure of the 25 items version (Wakabayashi et al., 2006) and of the 18 items version (Ling et al., 2009)

Table 3.1

Four factors structure of the 25 items version (Wakabayashi et al., 2006) and of the 18 items version (Ling et al., 2009)

FACTORS	AUTHORS	ITEMS
STRUCTURE	Wakabayashi et al. (2006)	15, 26, 37, 45, 48, 51
	Ling et al. (2009)	15, 26, 37, 45, 48, 51
DIY	Wakabayashi et al. (2006)	7, 18, 35
	Ling et al. (2009)	7, 18, 35
TOPOGRAPHY	Wakabayashi et al. (2006)	24, 31, 41, 49, 55
	Ling et al. (2009)	24, 31, 49
TECHNICITY	Wakabayashi et al. (2006)	5, 11, 20, 33, 40, 43
	Ling et al. (2009)	5, 11, 20, 33, 40, 43

Box 3.1 Research on the psychometric properties of the SQ

Research has investigated the psychometric properties of the SQ to test the validity of the unifactorial model and look for other latent constructs. Wakabayashi et al., (2006) conducted multivariate analyses on the SQ to investigate the factorial structure. A PCA suggested that SQ consisted of one-component (Eigenvalues = 7.92, 2.54, and 1.82) and in the first component 25 of 40 items loaded above .040, specifically they were items: 8, 10, 22, 12, 3, 39, 5, 14, 35, 34, 25, 6, 27, 23, 28, 30, 21, 32, 9, 16, 20, 37, 33, 7, 24, 25, 15, 38, 36, 13, 11, 2, 29, 40, 4, 26, 12, 17, 31 (from the highest to the lowest loadings). The Cronbach's α for these 25 items was .89. Correlation between the original 40 items and the 25 items version of the SQ was r=.95. Ling, Burton, Salt & Mucer (2009) tested the original 40-items SQ that had all items loading on to one systemizing factor and had the following fit statistics: χ^2=1347.77, df=740, p<.0005, TLI=.39, CFI=.42, RMSEA=.071 (.065-.077). The one-factor model for the original 40-item scale seemed not to be a good fit to the data. A reliability analysis of the 40-item SQ scale had a good Cronbach's α of .797, but the removal of 10 items increased the reliability to α=.815. The resulting 30-item one-factor model was analysed and had the following fit statistics χ^2=879.48, df=405, p<.0005, TLI=.44, CFI=.48, RMSEA=.084 (.077-.092). According to Ling et al. (2009) the unifactorial structure of the SQ was not supported by data so they examined the modification indices which highlighted improvements to the model by allowing items to load into different factors. The examination suggested that the SQ measured multiple latent constructs; specifically the authors grouped most of the 40 items into five categories that represented interests and abilities in DIY, technicity, structure of things, topography and taxonomy. Comparing results from Wakabayashi et al.'s (2006) study with the five categories found by Ling et al. (2009) it is found that some items of the shortened 25 items have correspondence with the 18 items version (table 5.5). Five items – 12, 13, 23, 34, and 57 -from the Wakabayashi et al.'s (2006) scale were not inserted in any factor because they either loaded on to multiple factors or could be linked to more than one factor. Ling et al., (2009) then tested first the one-factor 25 items version of the SQ proposed by Wakabayashi et al. (2006) and obtained the following fit statistics: χ^2=500.65, df=275, p<.0005, TLI=.59, CFI=.63, RMSEA=.071 (.061-.08). Then they tested the 20 items of Wakabayashi et al.'s (2006) , without 12, 13, 23, 34, 57 , that were allocated in their 4 factors (taxonomy was excluded) by having all items load on to one factor. The model had the following fit statistics: χ^2=312.25, df=170, p<.0005, TLI=.57, CFI=.62, RMSEA=.071 (.059-.084). However, when the 20 items were allowed to load on to four factors the fit statistics were the following: χ^2=213.87, df=164, p=.005, TLI=.85, CFI=.87, RMSEA=.043 (.024-.058) which was significantly better, χ^2=98.38, df=6, p<.0005. Further analysis of the modification indices suggest that the removal of items 41 and 55 would have improved the model. The fit statistics for a model "that includes a higher order factor of systemizing that each of these subfactors load on to are: χ^2=142.74, df=131, p=.228, TLI=.96 CFI=.97, RMSEA=.02 (.00-.046)" (p.544). The final 18 items version correlated well with the 40 items scale (r=.99, p<.0005) and had a reliability of .74. In a following study Ling et al. (2009) tested again the original 40-item scale, the 30 items model resulting from the reliability analysis they had conducted in the previous study, the 25 items scale proposed by Wakabayashi et al. (2006) and their final 18 items scale. The 40 items model with all items loading on to one systemizing factor had the following fit statistics: χ^2=1393, df=740, p<.0005, TLI=.47, CFI=.5, RMSEA=.073 (.067-.079). The 30 items model had the following fit statistics χ^2=889, df=405, p<.0005, TLI=.526, CFI=.56, RMSEA=.085 (.077-.092). The 25 items model (Wakabayashi et al., 2006) had the following fit statistics: χ^2=608.94, df=275, p<.0005, TLI=.59, CFI=.624, RMSEA=.086 (.076-.095). The 20-item model resulting from the exclusion of 5 items on the Wakabayashi et al.'s model was not a good fit either when considered as one factor - χ^2=416.59, df=170, p<.0005, TLI=.57, CFI=.62 RMSEA=.09 (.082-.105) – and when considered as four factor model - χ^2=294.83, df=164, p<.0005, TLI=.76, CFI=.80, RMSEA=.069 (.056-.082). Their 18 items four factor model had the best statistics: χ^2=172.52, df=129, p=.006, TLI=.90, CFI=.914, RMSEA=.045 (.025-.062).

Systemizing quotient-revised

The SQ-R (Wheelwright et al., 2006) was developed as a modified version of the original SQ (Baron-Cohen et al., 2003) in order to avoid the male bias that affects the original version, in which items pertains mostly to male domains. Differently to the original version, the SQ-R contains some items that cover social systems and domestic systems, while in the original SQ items refer mostly to mechanical or abstract systems. Noteworthy, the literature reports gender differences also for the SQ-R, with males scoring higher than females (Billington et al., 2008; Wheelwright et al., 2006).
Research confirmed that the SQ-R measures a single dimension of systemizing, and “is appropriate to use a summed SQ-R score to describe the extent to which an individual possesses a drive to systemize” (Allison, Baron-Cohen, Stone & Muncer, 2015).
The structure of the SQ-R is the same as the SQ, the only difference being that it comprises 75 items. “Strongly agree” scores 2 points and “slightly agree” scores 1 point on the following items: 1, 2, 4, 5, 7, 9, 11, 12, 13, 14, 16, 18, 19, 20, 21, 23, 25, 27, 29, 30, 32, 36, 38, 41, 42, 43, 46, 50, 53, 55, 60, 61, 62, 66, 68, 69, 72, 74 and 75. “Strongly disagree” scores 2 points and “slightly disagree” scores 1 point on the following items: 3, 6, 8, 10, 15, 17, 22, 24, 26, 28, 31, 33, 34, 35, 37, 39, 40, 44, 45, 47, 48, 49, 51, 52, 54, 56, 57, 58, 59, 63, 64, 65, 70, 71 and 73. The minimum total score is 0 and the maximum total score is 150.

3.4.2 Systemizing and hacking

Systemizing has recently been connected to hacking and studied in relation with both code breaking abilities and hacking expertise. Code breaking is a prototypical hacking task that requires to identify the key according to which a code is encrypted and to apply a transformation in order to decrypt the code thus obtaining intelligible information. It involves the ability to systemize as individuals have to analyse the code, find the pattern (i.e. the rule) of transformation and apply it to the cypher-text (input) to obtain the plaintext (output). Lawson (2005) administered a code breaking questionnaire as a means to measure systemizing ability to a group of AS males, non-AS males and non-AS females. The questionnaire was a collection of progressively difficult codes that participants had to decipher using cryptanalysis. Participants were presented with an encoded target (input) and had either to identify the rule that led to its decoded form (provided) or to understand how to decode it (i.e. turn it into an output). The author found a significant difference between non-AS females and non-AS males, consistent with the empathising-systemizing theory of sex differences. However, no significant difference was found between the two male samples (AS and non-AS).

Schell and Melnychuk (2011) tested hacker conference attendees' with the AQ. The authors found that the majority of the hacker conference attendees had overall AQ scores ranging from 17 to 32, which is in an intermediate position between the general population and ASC individuals. Compared to the recently published data about the distribution of AQ scores in ASC and the general population (Ruzich, Allison, Smith, Watson, Auyeung, Ring & Baron-Cohen, 2015), hackers' range of scores was higher than that of the general population (range: 11.6 - 20.0) and partly overlapped with that of the ASC group (range: 27.6 - 41.1). This is consistent with the hypothesis of a connection between hacking and subclinical AS traits, and with previous studies (Baron-Cohen, 2001; Schell et al., 2002), which reported that controls and university students in the humanities and social sciences tend to obtain lower scores (i.e. scores equal to or below 16), while those diagnosed as having debilitating AS traits reported scores in the high range (AQ scores of 34 or higher). Within the five domains tested by the AQ – social skill, attention switching, attention to detail, communication, and imagination – the domain that the hacker conference attendees scored highest on related to 'exceptional attention to local details', followed by 'strong focus of attention'. In addition, five of the six items that the overall group of hacker conference attendees agreed with most belong to the attention to detail subscale.

Schell and Melnychuck's (2011) findings were more recently replicated and extended by Harvey, Bolgan, Mosca, McLean and Rusconi (2016). The authors conducted a study on students from an ethical hacking course, to investigate whether hackers express higher autistic traits than non-hackers and if there is a relation between these autistic traits and actual performance in hacking tasks. Researchers used the AQ, the SQ and behavioural tasks – prototypical code breaking challenges - to assess hacking performance and a control task focused on x-ray image interpretation skills. This study showed that hackers obtained higher scores than non-hackers in the AQ, in the attention to detail subscale and in the SQ; that SQ scores were related with code-breaking performance, while attention to detail scores were related with performance in the x-ray screening task.

It is important to recall here that a general feature of systemizing and of the autistic brain in general is excellent attention to relevant detail (Baron-Cohen, 2008; Baron-Cohen, Ashwin, Ashwin, Tavasso & Chakrabarti, 2009). According to Baron-Cohen's theorization of systemizing, attention to detail is directed toward detecting input-operation-output reasoning and this law-based pattern recognition system can produce talent in systemizable domains (Baron-Cohen et al., 2009, p. 1376). Central to this thesis is Baron-Cohen's account of systemizing and the hypothesis that systemizing might be highly expressed in hackers; specifically, it is hypothesised that hackers possess a strong attention to detail which is targeted to the understanding of how a system, in this case consisting of computers and networks, works. The finding that there is a relationship between the SQ scores and the ability to solve code breaking challenges supports the hypothesis that hackers might possess strong systematic traits. This might be explained considering that, typically, hacking tasks involve a high degree of systematic thinking and require the ability to analyse rules and patterns governing a system.

In addition to code breaking, a most prototypical and specialized hacking task, by which the theoretical link between systemizing thinking and hacking may be well exemplified, is penetration testing. Indeed, penetration testing appears to embed all components of the systemizing approach highlighted in Baron-Cohen's account. The figure reported below shows the commonalities between the different phases of systemizing and the phases of penetration testing.

SYSTEMIZING		PENETRATION TESTING
ANALYSIS	Observation input-output Local level of analysis	ACTIVE RECONNAISSANCE SCANNING PORT AND VULNERABILITIES
OPERATION	Operation on input Change on output	SCANNING
REPETITION	Repetition of phase 2	SCANNING
LAW DERIVATION	Law formulation	EXPLOITATION
CONFIRMATION/ DISCONFIRMATION	Law retained or modified	MAINTAINING ACCESS

Table 3.2 Comparison between systemizing phases and penetration testing phases – see explanation in text.

The process of systemizing involves five different stages, all necessary to penetration testing. The first phase is the analysis in which the subject observes the system looking for the input-output mechanism and studies its functioning. This is reflected in the first two phases of penetration testing, namely reconnaissance and port/vulnerabilities scanning. In these first steps of penetration testing the hacker performs a thorough research on the target, trying to gather as much information as it can be found. Then in the following phase all the system ports are scanned in search for vulnerabilities and holes. The main aim of the scanning phase is to gain access to the system itself.

In the scanning phase, three different systemizing processes are involved – analysis, operation, repetition. The hacker observes the behaviour of the system, then does some operations on it to see how it reacts, that is, what effects changing the input has to the modification of the output. This is repeated until the hacker is able to understand the rules governing the system’s functioning. The law-derivation phase is reflected then in the actual exploitation phase in which the hacker attempts to penetrate the system and to gain access to it. Depending on the outcome of the exploitation phase – i.e. if it has been successful or not -, the rule is retained or not. After having exploited the system, the goal is to maintain access to the system itself. This implies that if the law derived was correct, it can be confirmed; otherwise it has to be disconfirmed and modified. All these tasks require high attention to detail and the ability to analyse rules and patterns governing a system's behaviour and functioning.

In the following paragraphs, the relationship between systemizing and a series of cognitive abilities is discussed in light of research findings. The hypothesis that these abilities might be relevant in a hacking context is also discussed. The following discussion will provide the rationale for the choice of the psychological tasks that were used in the studies that are part of this thesis and that will be fully described in the methods section.

3.4.3 Systemizing, attention to detail and cognitive abilities/processing styles

Cognitive abilities that exhibit a male advantage and involve a high degree of systematic thinking have been investigated in relation with self-report measures of systemizing to test the E-S theory of sex differences. In the following paragraphs research investigating the relationship between (self-reported) systemizing or attention to detail traits and cognitive abilities is discussed. Interestingly, SQ and the attention to detail subscale of AQ showed significant correlations with performance in cognitive tasks that have also been linked with programming proficiency, as reviewed before.

3.4.3.1 **Systemizing and Intelligence**

Ling et al. (2009) investigated the relationship between SQ and intelligence. They gave participants the 60-item version of the SQ, a shortened 18-item version of the SQ, the Mental Rotation Test[11] (MRT; Shepard & Metzler, 1971) and the Baddeley (1968) three minute reasoning test as a measure of reasoning ability useful in evaluating intelligence (Kane, 2005). Overall the results supported Baron-Cohen's view that SQ is not related to intelligence as neither the original 60-item version nor the shortened 18-item version of the SQ developed by the authors showed significant correlations with the three minute reasoning test (but SQ and its shortened version correlated with the MRT as discussed below). A similar conclusion was reached by Morsanyi et al. (2012), who found no correlation between the shortened 18-item version of the SQ (Ling et al., 2009) and fluid intelligence as measured with a short form of the Raven Advanced Progressive Matrices (APM-SF; Arthur & Day, 1994).

[11] Findings about MRT will be discussed below

3.4.3.2 **Visuo-spatial abilities**

Systemizing is thought to play a role in visuo-spatial ability tasks such as mental rotation (Baron-Cohen, 2008; Ling et al., 2009) because they involve detecting a rule in a system and predicting how each feature will appear after the transformation (Collins & Kimura, 1997).

Cook and Saucier (2010) conducted two studies to investigate the relationship between mental rotation and targeting – two spatial tasks – and the ability to empathize and systemize as measured with the SQ and the Empathy Quotient (EQ; Baron Cohen & Wheelwright, 2004). They tested a sample of 97 undergraduate students with the SQ, the EQ, the Reading the Mind in the Eyes test[12] (RMET; Baron-Cohen, Jolliffe, Mortimore, & Robertson, 1997) the MRT, and a targeting task measuring the accuracy with which participants hit a target. Consistent with the literature, they found that men obtained higher scores than women on the SQ and they outperformed women on both MRT and targeting with their dominant hand as well as with their non-dominant hand, whereas women scored higher on the EQ. Moreover, the MRT score was significantly predicted by the EQ (with a negative regression coefficient), SQ (positive) and RMET (positive[13]); the multiple regression model was overall significant ($R^2=.267$, $F(3,84) = 10.191$, $p<.0001$). SQ scores also significantly predicted targeting performance for the dominant hand and for the non-dominant hand. Zero-order correlations were investigated and SQ scores did not show any significant correlation with mental rotation. Contrary to this finding, however, Ling, Burton, Salt and Muncer (2009) found that a shortened 18-item version of the SQ was significantly correlated with mental rotation scores.

Literature reports a relationship between performance in tasks that load on to another visuo-spatial ability – i.e. visual working memory- and the attention to detail subscale of the AQ in the general population (Richmond et al., 2013). Richmond et al. (2013) conducted a study with 104 college students; autistic traits were measured with the AQ and scores were broken down into two different subscales: attention to detail and social interaction factors. Visual working memory was investigated using a variant

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[12] In the RMET participants were presented with 28 photographs of the eye region of the face. They were asked to pick which of 4 words best describes what the person in the photo is thinking or feeling.
[13] This was in the opposite direction of the predicted hypothesis.

of the sequential comparison procedure developed by Phillips (1974) and articulated in two different tasks – an object order task and an object recognition task. Participants were shown a series of four novel shapes, presented sequentially for 1 second each; in the first task participants were asked to judge which of two target shapes were presented first in the series; in the second the task was to judge whether the target shape was presented or not in the series. The authors found that the attention to detail subscale was positively associated with the object recognition task but not with the order recognition task; no explanation was given as to why there was no correlation in this latter task. They concluded that findings supported overall the idea that the detail focused cognitive style, that is characteristic of ASC, correlate with performance on tasks that involve visual working memory ability and recommended more systematic studies in the future.

3.4.3.3 **Systemizing and field dependence/independence**

The drive to systemize has been related to a predisposition towards field independence (Chao, Huang, & Li, 2003), and this is consistent with the conceptualization of systemizing as a drive to analyse elements of a system because the analysis and understanding of the interaction of its different parts should be facilitated by a bias towards detail and the ability to ignore perceptual distractors. Field independence describes a tendency to provide structure to a situation that is relatively unstructured (Bishop-Clark, 1995). When perceiving information, a field independent person is likely to overcome the organization of the field and restructure it. On the contrary, in field-dependent people the surrounding field is likely to have a strong impact on their perception of an item in the field (Bishop-Clark, 1995). Measures of field independence – e.g. EFT, Group Embedded Figure Test (GEFT; Oltman, Raskin, & Witkin,1971) and Navon task – have been widely investigated in relationship with systemizing traits. According to the EMB theory, the EFT and the GEFT are measures of attention to detail which is a prerequisite for systemizing (Baron-Cohen, Ashwin, Ashwin, Tavassoli, & Chakrabarti, 2009). Before discussing the relationship between GEFT and systemizing, it should be explained that the original authors did not specify a clear cut-off score for identifying field-dependent and field-independent individuals. Different cut-offs have been used by different researchers for classification purposes (Cakan ,2003). Some have used the 27% rule: subjects with raw scores in the upper 27% of scorers are considered field-independent while subjects with raw scores in the lower 27% are considered field-dependent (Cureton, 1957; Lu & Suen, 1995). Shih and Gamon (2001) used the national mean score of 11.4 as the criterion: higher scores were considered indicative of field-independence while lower scores were considered indicative of field-dependence. Other researchers considered to be field-independent those with scores between 0 and 5 as field-dependent those with scores between 13 and 18 (Foell & Fritz, 1995). Saracho (2001) considered representative of field-independence the top third of scores and representative of field-dependence the bottom third of scores. To date, no studies have assessed GEFT and systemizing using SQ or its revised version (SQ-R; Wheelwright , Baron-Cohena, Goldenfeld , Delaney, Fine, Smith, Weil & Wakabayashi, 2006) within the same participants. However, Brosnan, Gwilliam and Walker (2012) investigated the relationship between EFT and systemizing assessed with the Intuitive Physics Test (Baron-Cohen, Wheelwright, Scahill, Lawson & Spong, 2001), a multiple choice test in which participants have to select the correct response to 20 questions relating physics principles among 4 options. The EFT requires participants to decide which one of two simple shapes is embedded in a more complex figure. Brosnan et al.'s materials comprised also the Friedberg Visual Acuity and Contrast Test (FrACT ver 3.3.5., Bach 1996), because they wanted to see whether performance in the EFT is supported by enhanced visual acuity and whether both together can enhance systemizing ability. Comparing participants with ASC and the control group they found that ASC participants had better performance and faster reaction times than the control group in the EFT. Regression analyses found that there was a significant relationship between visual acuity and inverse efficiency in the EFT ($\beta=.65$, $p<.001$, $R^2=40.4\%$), and between systemizing and inverse efficiency in the EFT ($\beta=.43$, $p=.028$, $R^2=15.2\%$), although when applying Bonferroni correction for multiple tests only the relationship between visual acuity and inverse efficiency in the EFT remained significant. Billington, Baron-Cohen and Bohr (2010) investigated empirically the relationship between systemizing and field independence using the Navon task. Performance on this task is likely to be influenced by multiple factors, including perceptual bias (local/global) and attentional control mechanisms that allow to avoid distractors while focusing on the target (Billington et al., 2010). Billington et al.'s hypothesis was that "increasing systemizing score would be associated with reaction time preference for local targets, reflecting a local precedence effect during the processing of hierarchical stimuli" (p.512). It was expected that high systemizers would be faster on incongruent trials when the target is at a local level (local precedence), consistent with local advantage and local interference effects (Billington et al., 2010, p. 512). The sample comprised 20 normal individuals who were given the SQ-R and the Navon task. From the Navon task four scores were created: a) local/global precedence, b) global interference, c) local interference, d) overall interference. No significant effect of gender was found on the SQ-R, even though males (mean=60.22, SD=25.65) did score higher than females (mean=56.55, SD=30.57). This can be due to the small sample size (the authors reported a power of <0.6 for their test). Significant correlations were found between SQ-R and local/global precedence when corrected for sex (partial $r = .570$, d.f. = 17, $p<.005$), and between SQ-R and local interference (partial $r=.446$, $n=17$, $p<.05$), but not between SQ-R and global interference. These findings indicate that strong systemizers showed a bias towards attending to the local level and an increased effect of local-level distractors.

3.5 Task selection rationale

The cognitive abilities and cognitive style outlined above showed a relationship with either systemizing or attention to detail, which is a prerequisite of the drive to systemize. As discussed in Chapter 2, they have also been linked with programming proficiency and this relationship is supported by research findings. The core aim here is the investigation of cognitive skills and abilities that might be significantly related with hacking proficiency. Given that programming is a fundamental prerequisite for hacking proficiency and that the latter has recently been linked with systemizing (Harvey et al., 2016), the hypothesis formulated here was that visuo-spatial abilities and field independence might have a close relation with hacking(-like) skills.

3.5.1 Field independence

There is evidence that field independent people tend to choose structured fields such as mathematics, science, engineering (Witkin, Moore, Goodenough, & Cox, 1977). As reported by Bishop and Clark (1995), thirteen empirical studies examined the relation between this construct and computer programming. Albeit the size of the correlations found varies considerably, in all studies field independence correlates with programming achievement score. The overall average weighted correlation is .45 (Bishop & Clark, 1995, p. 245). Field-independent students are better problem solvers than field-dependent ones; moreover, in learning programming languages and learning the patterns that appear within solutions, field independent individuals are advantaged in that they are more able to generate structural rules (Ronning, 1984). Additionally, given that hackers have higher scores on the attention to detail subscale of the AQ (Harvey et al., 2016) and given that hacking tasks such as penetration testing require the ability to attend to the details of a systems' functioning, it is plausible to hypothesize that a field-independent cognitive style might be associated with enhanced hacking skills.

To assess field independence the Group Embedded Figure test was used (GEFT; Oltman et al., 1971). It was chosen because it is the measure of field dependence/independence cognitive style used in the studies reviewed at the beginning of this thesis. Research on both programming and ASC used the GEFT; as a valid instrument to assess the type of cognitive style. Using the GEFT allows to draw a comparison between findings from the present study and the ones found in the literature.

On one hand Mancy and Reid (2004) showed that field independency as measured by the EFT was related with programming performance; on the other hand, field independence was found to correlate with systemizing as assessed with the Intuitive Physics test (Baron-Cohen et al., 2001). The use of GEFT in this thesis allows comparison with previous studies and on the other hand provides new insight on the relationship between systemizing and field independence using the SQ as a measure of systemizing.

3.5.2 Visuo spatial abilities

Visuo-spatial abilities – including mental rotation ability – have been associated with success in mathematics and science courses (Delgado & Prieto, 2004), with performance on standardized tests such as the SAT and the choice of mathematics and science as majors in college (Casey, Nuttall, Pezaris, & Benbow, 1995). As Norman (2008) reported, visuo-spatial ability has been proved to have a strong correlation ranging from 0.35 to 0.50 with performance on a computer search task (Norman & Butler, 1989), menu selection and navigation tasks (Chen & Rada, 1996) and command and control tasks (Murphy, 2000). The author suggests that visuo-spatial ability is such an important cognitive ability in Human-Computer Interaction (HCI) because human-computer interface has many spatial aspects to it. “HCI invokes the same cognitive abilities as mentally folding a surface, creating an effect, unfolding the surface, and inferring what it has been created or one’s position” (Norman, 2008, pp. 231-232). HCI is essentially a flat, narrow and convoluted passageway into a multidimensional, hierarchical space. Spatial visualization can be assessed through different tests: mental rotation test, paper folding test, surface development and form board tasks, all of which require to mentally manipulate 2-dimensional and 3-dimensional figures. Given that hackers work with computer systems and that mental rotation abilities are correlated with performance on computer tasks, it is plausible to hypothesize that mental rotation abilities might have a correlation with hacking expertise. The mental rotation test was used among the other measures to assess mental rotation ability.The choice to use MRT was motivated by the need to have a validated measure and to be able to draw a comparison between results from the present study and previous results from the literature. The relationship between programming and mental rotation was assessed using different diagnostic tasks – paper folding test, map sketching, searching a phone book, a study process questionnaire – (Simon et al., 2006). Although the studies did not use the MRT itself, the mental rotation ability is widely recognized as having a relationship with programming (Cherney, 2008; Feng et al., 2007; Jones & Burnett, 2008). Within the field of studies on autism, systemizing as assessed with the Systemizing Questionnaire was related with performance on MRT (Ling et al., 2009). Previous investigation though did not find a significant correlation between MRT and the SQ (Baron-Cohen et al., 1997); so this thesis can contribute to the investigation of the relationship between the two constructs by providing additional data.

Visual working memory is another fundamental visuo-spatial ability, and it represents the active maintenance of visual information to serve the needs of ongoing tasks (Luck & Vogel, 2013). Interestingly, Johnstone and Wham (1982) suggested that visual working memory overload appears to occur when the individual cannot differentiate the “message” or important information from the non-essential information. The field independent person is capable of using his or her working memory space more efficiently simply because it is not becoming cluttered with information irrelevant to the problem being faced (Mancy & Reid, 2004, p. iii). Research shows that visual working memory space and field dependency are useful

predictors of success in conceptual areas such as mathematics and statistics (Mancy & Reid, 2004). Working memory space is important also in problem solving as it helps to keep track of goals and sub-plans (Carpenter, Just & Shell, 1990), and therefore is important for programming, as these two latter are recognised skills for programming.
Classic measures of visual working memory are the Complex Figure Rey test (Rey, 1941), the sequential comparison procedure (Phillips, 1974) and its variant (Luck & Vogel, 1997). For the present thesis it was chosen to use a variant of the experimental procedure used by Richmond et al. (2013); the choice was motivated by the consideration that the authors found a correlation between the attention to detail subscale of the AQ and a visual working memory task – i.e. the object recognition task- but not another visual working memory task – i.e. the order recognition task. In this study the interest was to investigate whether one or both visual working memory tasks showed a correlation also with the systemizing questionnaire whether there was a a correlation between the visual working memory task and hacking expertise.
In the battery used for the purpose of this project, and fully explained in the methods section of Chapter 5, the choice of tasks was based on the research discussed in this Chapter. The GEFT and the Navon task were used to assess field independency, the variant of the sequential comparison task proposed by Richmond et al. (2013) was used to assess visual working memory, and the MRT was also administered. As a mean to assess intelligence, the Raven Standard Matrices short version was also administrated.

3.6 Conclusions

In this chapter recent findings suggesting that hacking abilities may be related to systemizing and attention to detail were reviewed.
Systemizing is the drive to analyse and understand systems functioning in order to predict its behaviour, it is a concept that works only on systems that are 99% lawful, and an example of such systems is computer systems. Hacking involves a deep knowledge of how computers, programming and information networks work as a system, and how these could be manipulated so it is plausible to hypothesize that they might have higher systemizing abilities compared to the general population. Evidence supporting this hypothesis is that hackers reported higher score on the attention to detail subscale of the AQ, and that literature reports that some cognitive skills and cognitive styles that have been studied in relation to systemizing have also been reported to be

important for programming abilities. Specifically, mental rotation ability is considered to be important in programming and research has shown a correlation with measures of mental rotation and systemizing. A field independent cognitive style has a positive correlation with programming and is also considered to be a measure of systemizing. Visual working memory capacity is correlated with a field independent cognitive style and, although it has not been studied in relation to programming expertise or directly with systemizing, it was correlated with the attention to detail subscale of the AQ. For all these reasons, the hypothesis that systemizing together with visuo-spatial abilities such as mental rotation and visual working memory and field independence might be related with hacking expertise was put forward.

The choice of the measures chosen was discussed in the paragraphs above. The main interests in the present thesis are either to compare results found in the studies conducted with the ones given in the literature; and to add new data to investigate the relationships between self-report measures of systemizing – the Systemizing Quotient and the Systemizing Quotient revised – and cognitive measures.

In the following chapters – 4, 5, 6 – the three studies conducted within the PhD are described and results are discussed. Study 1 (described in Chapter 4) represents the starting point of the project, i.e. an investigation of the distribution of the systemizing traits in the hackers' population compared to non-hackers.

Results found that within the total sample there is indeed a difference in that hackers showed higher scores on the SQ- revised compared to non-hackers. When considering only the male sample, though, the difference was not significant anymore. These results needed further investigation so another experiment was designed adding other variables to be measured,

Study 2 (described in Chapter 5) aims at investigating the distribution of systemizing traits within the general population, and the investigation of the relationship between systemizing scores and performance on cognitive tasks. It was an exploratory study in which the initial hypotheses were tested within a sample of Italian participants. The choice to administer the experiment to Italian population was due to the fact that I am Italian an I have far more contacts within the Italian population rather than the English one.

Study 3 (described in Chapter 6) applies the same rationale of Study 2 but in this case the target population is the hackers. For this reason, to investigate hacking expertise, another assessment instrument was initially added to the battery, i.e. a capture the flag challenge. It is made by different tests that aim to measure specific hacking expertise. Results found in Study 2 partially supported the initial hypotheses so in Study 3 I wanted to see whether the same results could be found also within the hackers' population and whether there were individual differences between hackers and non-hackers on performances on the different measures.

4 STUDY 1 – Testing (ethical) hackers with the Systemizing Quotient-Revised (SQ-R) and a novel scale

4.1 Introduction

The first study consisted in the administration of two self-report measures to a sample of ethical hackers and to students from other disciplines. This study was an explorative one and aimed at looking for the distribution of SQ-R scores (Wheelwright et al., 2006) in individuals with (ethical)[14] hacking expertise compared with students from other disciplines and at testing the validity of a novel scale. This scale was specifically developed to measure problem solving skills and creativity, traits that the literature reports to be characteristics of hackers. Theoretically the novel scale would be able to assess constructs that are not already covered by the SQ-R and therefore would represent a complementary assessment. So, other than the investigation of the distribution of SQ-R scores among hackers compared to non-hackers, this first study also represents the Question Testing stage that followed the Developmental stage (see section 4.1.3) in the creation of a potentially useful novel scale. In the field of survey methodology three main stages of question testing have been identified (de Leeuw, Hox & Dillman, 2008): 1) The Developmental stage; 2) The Question testing stage; 3) The Dress Reharsal. In the present research, the Developmental stage consisted firstly in a thorough exploration of the concept to be measured through a study of the literature and of the survey methodology in general. This first preliminary phase was characterized by a qualitative approach. Secondly, once the concept to be investigated was clear, the questions were created according to the guidelines and recommendations of the community of survey experts (de Leeuw et al., 2008). The Question Testing stage here described consisted in the testing of the full draft questionnaire, in order to check its validity. The final stage – i.e. the Dress Reharsal - consisted in a second test of the questionnaire, after a few modifications based on the results of Study 1, with a much larger sample of participants and was performed in Study 2 and Study 3.

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[14]The word “ethical” is here in brackets as the aim of the present thesis is to investigate skills and traits that are expected to be shared among all hackers, independently from the ethical connotations of their activities. From now on it will be used just the word “hacker”.

In order to develop the novel scale, I attended a two weeks course on research methods, specifically on building surveys, in Utrecht, Netherlands. The course guided the students through all the phases of surveys development, from questions3 writing to analysing data with SPSS. The development of the novel scale used in this research mirrors the knowledge learnt in this course, and the analyses done mirrors the Principal Component Analyses learnt in Utrecht. At first the concept to be investigated were chosen – problem solving and creativity. According to the literature these two constructs are characteristics of hackers and the aim was to build a novel instrument able to assess these two constructs. The instruments present in the literature were not useful (perche?) so I decided to develop another one.

Initially I created a set of questions based on the guidelines on the best practice. The set of questions were created based on the literature review and on a focus group I conducted with 5 students from the Ethical Hacking degree at Abertay University. Accordingly to the literature, focus groups are suggested as a best practice to test the questions of self-completion questionnaires. On one hand, focus groups allows to explore new ideas or concepts in the developmental stage of the questionnaire, on the other hand they provide feedback from participants about the survey questions (de Leeuw et al., 2008).

The questions were then reviewed by 5 other hackers and 5 non-hackers to assess their content validity, readability and clarity. Also, I wanted to reduce the potential for misunderstanding and ambiguity by having clear and simple questions.

Accordingly to the feedback given by the independent evaluators, the questions were then modified and corrected. The initial draft of the scale was then tested and administered to a sample of 10 students from the ethical hacking degree and 10 students from other degrees; all were students at Abertay University.

The standards by which the goodness of a question is measured are reliability and validity (de Leeuw, Hox, Dillman, 2008). Validity refers to the correspondence between the answer to the question and the true value for the construct being measured (de Leeuw et al., 2008). Reliability refers to the fact that the question maintains the same meaning through time and the same meaning for different respondents.

None of the existing scales was suitable for the purpose of the present thesis, i.e. specifically assess creativity in the domain of problem solving. The Creative Achievement Questionnaire, the Biographical Inventory of Creative Behaviours, the revised Creative Behaviour Inventory and the Creative Domain Questionnaire were reviewed but none of them specifically targeted the domain of interest for this study. After reviewing the existing instruments, I proceeded with the creation of a set of new items. The process started with a focus group with students from ethical hacking courses, conducted to explore and discuss the idea of creativity and problem solving and write down a preliminary series of questions. The questions were then reviewed by 10 students from ethical hacking and 10 students from psychology to examine the readability and comprehensibility of the questions. Feedback was convergent so a final draft of 13 questions was pilot tested in Study 1.

The main hypotheses derived from the literature review that guided Study 1 were that (1) those with hacking expertise are characterized by a strong drive to systemize resulting in higher scores on the SQ-R compared to the general population; and (2) hackers possess strong problem solving skills and creativity traits that would result in higher scores on the novel scale compared to the general population. Additional self-report information was collected concerning the amount of time spent weekly in hacking activities by our participants. The correlation between time spent in hacking activities, SQ-R and the novel scale score was also tested, as it could provide useful converging evidence on the link between systemizing, problem solving and creativity, and interest in hacking.

4.2 Methods

4.2.1 Participants

161 participants volunteered to complete the questionnaires. 89 participants were males (55.3 %) and 72 were females (44.7 %). Respondents' age ranged from 18 to 60 (mean = 23.46, median = 21, SD=6.87). 64 participants were hackers (39.8 %) and 97 participants were not hackers (60.2 %). Among the hackers group, 43 were students (67.2 %), 20 were employed (31.3 %) and 1 subject was unemployed (1.6 %). Among the non-hackers group 91 were students (93.8 %), 5 were employed (5.2 %) and 1 participant was unemployed (1 %). The academic background for the hackers group was

a degree on ethical hacking. The academic background for the non-hackers group was distributed as follows: 81 psychology (83.5 %), 5 sociology (5.2 %), 3 physics (3.1 %), 3 computer science/programming (3.1 %) and 5 did not provide an answer. One female participant was removed as an outlier, according to the outlier labelling rule explained below so data from 160 participants were retained for the final analysis. The study was approved by the School of Health and Social sciences Ethics Committee at Abertay University (see Appendix 1).

4.2.2 Apparatus and Stimuli

The paper-and-pen self-report instrument contained the SQ-R (Wheelwright et al., 2006) and a novel scale. The novel scale items were appended at the end of the SQ-R rather than presented as a separate questionnaire, as they were construed as a potential integration to the SQ-R rather than a replacement for it and they had the same response options.

Demographics

A series of demographic questions was presented on the first page: 1. “What is your gender?”; 2. “What is your age?”; 3. “What is your Country of Residence?”; 4. “What is the highest level of education you have completed? (options: Doctoral or professional degree, Master’s degree, Bachelor’s degree, Associate’s degree, Postsecondary no-degree award, Some college - no degree, High school diploma or equivalent, Less than high school, Other)”; 5. “Which is your current employment status?”; 6. “Which is your degree subject?”; 7. “Percentage of time spent on hacking activities weekly (options:0-10%, 10-20%, 20-30%, 30-40% , 40-50% , 50-60% , 60-70% , 70-80% , 80-90% , 90-100%)”. All questions were open-ended except for questions 4 and 7 in which participants had to thick the box corresponding to the desired answer.

Systemizing quotient-revised

The SQ-R (Wheelwright et al., 2006) was used. As described in paragraph 3.4.1, it is a self-report questionnaire with 75 questions to which the subject has to indicate the degree to which he or she agrees with using a 4 point Likert scale. The choice to the SQ-r was motivated by the fact that even if it is slightly longer than the original SQ, in this first study there were no problems of time constraints. The administration took place in person and the only instrument administered was the SQ together with the novel scale and some demographic questions; all together it took about 15 minutes to complete.

Novel scale

This scale was developed with the aim to capture traits that may subtend specific features of hackers' mind-set. A thorough research based on the existing literature on hackers and on related online blogs, articles and materials discussing hacking led to the creation of an initial set of 13 items. These 13 items were then given to 6 hackers and to 6 non-hackers to check their readability and comprehensibility. All reviewers returned with concordant feedback on the meaning of the items and on the appropriateness of the sentences construction. The item structure of the novel scale is identical to the one used for the SQ-R. There are four response options: "strongly agree", "slightly agree", "slightly disagree", "strongly disagree". "Definitely agree" responses score two points and "slightly agree" responses score one point in the following items: 1, 3, 5, 7, 9, 11. "Definitely disagree" responses score two points and "slightly disagree" responses score one point on the following items: 2, 4, 6, 8, 10, 12, 13. The remainder of the response options score 0. The minimum total score of the scale is 0 and the maximum is 26. Items 1, 3, 4, 10, 11 were designed to target the construct of resourcefulness and curiosity, items 2, 5, 6, 7, 8, 9, 12 and 13 were designed to measure the construct of problem solving. These two constructs are not tackled by the systemizing quotient, as the questionnaire was developed to assess interests in different kinds of systems (Baron-Cohen et al., 2003). The hypothesis was that, other than the ability to systemize, to perform a successful hack one needs also resourcefulness, creativity and problem solving abilities. Hacking consists in trying to make systems work in ways they were never intended to work or in finding vulnerabilities that were not known to the developers. As a result, a hacker needs to first understand how the systems work and then think creatively about how to operate on the systems (see https://null-byte.wonderhowto.com/forum/problem-solving-is-essential-hacker-skill-0150882/). All items included in the novel scale are reported in the table below.

Table 4.1 Novel scale items.

Table 4.1

Novel scale items (reverse scored items are indicated with an asterisk *).

		Strongly Agree	slightly agree	Slightly Disagree	strongly disagree
1	I like trying new things				
2	*I do not think it is necessary to come up with new solutions to a problem if the one I've used in the past was successful				
3	I would define myself as a type of person who thinks 'outside the box'				
4	*I do not like learning new things				
5	I believe that no matter what life throws at me, I will be able to handle it				
6	*I often get stuck and ask other for help				
7	When I encounter a problem, I usually look at it from different perspectives in order to come up with the best solution				
8	*I am afraid of making a mistake and usually this affects the decision I make				
9	I am good at finding solutions to problems that other would not be able to solve				
10	*I do not feel comfortable with taking new perspectives into things				
11	I have been told I am a creative person				
12	*When I find a way to solve a situation I do not feel the curiosity to find another way to solve it				
13	*I feel uncomfortable in taking snap decisions				

4.2.3 Procedure

Questionnaire administration took place at Abertay University. It started at one of the annual Securi-Tay Conferences organized by the Abertay University Ethical Hacking society. Securi-Tay is a conference about hacking and computer security and attracts students and professionals in the field of cyber-security and ethical hacking. The administration continued in the following months with students from different degrees. Participants were recruited in person by the researcher and asked if they wanted to volunteer to complete the questionnaires; the completion of the questionnaire was made on the spot and it took about 10 minutes each. Those who agreed to participate were given the five pages self-report instrument described above. Before completing the self-report measure, an informed consent form was presented to participants and once they completed the questionnaires they were properly debriefed.

4.3 Data analysis

Individual item scores were treated as ordinal variables, as in any situation in which people are asked to rate something subjective it is good practice to treat data as ordinal (Field, 2009). The total score of either questionnaire (SQ-R or novel scale) was instead regarded as ratio data being a continuous variable that gives a score for each person on a scale with a true and meaningful zero point.

Items scores and total scores were used as dependent variables. Principal component analyses were conducted on the novel scale to investigate its component structure. Components were assumed to be correlated so promax rotation was used. Comparisons between means were performed to check any effect of gender or subject degree in the SQ-R total score and in the novel scale total score. Extreme outliers were identified and removed according to the outlier labelling rule (Hoaglin, Iglewitz & Tukey, 1986) that allows to identify the lower and upper demarcation point using the following formulas respectively: Q3+ (1.5*(Q3-Q1)) and Q1-(1.5*(Q3-Q1)), where Q stands for Quartile, Q3 is the 75th Percentile and Q1 is the 25th Percentile.

4.4 Results

4.4.1 Descriptive statistics

SQ-R scores ranged from 13 to 105 with a mean of 61.62 (SD=19.661); Novel scale scores ranged from 2 to 23, with a mean of 12.36 (SD=.384). For the SQ-R the mean score for males was 64.74 (SD=18.798) and for females was 57.72 (SD=20.149). For the novel scale, the mean score for males was 13.25 (SD=4.934) and for females was 11.24 (SD=4.556). For the hackers group, mean score on the SQ-R was 65.44 (SD=18.590) and mean score on the novel scale was 13.06 (SD=5.080). For the non-hackers group, mean score on the SQ-R was 59.08 (SD=20.037) and mean score on the novel scale was 11.89 (SD=4.674). As regards the time spent on hacking activities, hackers spent an average of 40% of time on hacking activities weekly while non-hackers reported not spending any time on hacking activities. Within the hackers group percentage of time spent on hacking was distributed as follows: 3 participants spent 0-10%, 11 participants spent 10-20%, 9 participants spent 20-30%, 7 participants spent 30-40%, 11 participants spent 40-50%, 12 participants spent 50-60%, 4 participants spent 60-70%, 6 participants spent 70-80% and 1 participant spent 90-100%.

A summary of descriptive statistics for males and females and hackers vs. non-hackers is reported in the following tables.

Table 4.2 Descriptive statistics for SQ-R.

Table 4.2

Descriptive statistics for SQ-R according to gender and hacker vs. non-hacker

		Mean	Median	SD	IQR
Male	Hacker (N=56)	64.30 (2.508)	65.50	18.765	26
	Non-hacker (N=33)	65.48 (3.329)	63.00	19.122	30
Female	Hacker (N=8)	73.38 (5.713)	76.00	16.159	27
	Non-hacker (N=33)	55.73 (2.498)	53.00	19.830	27

Table 4.3 Descriptive statistics for novel scale

Table 4.3

Descriptive statistics for novel scale according to gender and hacker vs. non-hacker

		Mean	Median	SD	IQR
Male	Hacker (N=56)	13.14 (.678)	13.50	5.072	8
	Non hacker (N=33)	13.42 (.829)	13.00	4.763	7
Female	Hacker (N=8)	12.50 (1.927)	11.00	5.451	9
	Non hacker (N=33)	11.08 (.561)	12.00	4.455	7

4.4.2 Parametric assumptions check

An initial check for compliance of the data with parametric assumptions was performed to choose the most appropriate statistical tests according to a hacker (hackers, non-hackers) by gender (male, female) design.

(1) Random distribution: subjects were randomly selected from the available population, approached individually and tested only once, therefore every set of observations in the sample is independent from the others.

(2) Normality assumptions: mean and median were not similar except for the distribution of scores in the novel scale for males, both hackers and non-hackers. The standard deviation was smaller than the mean in all conditions for both questionnaires.

Values of skeweness and kurtosis revealed a non-normal distribution for all conditions in both questionnaires. To obtain further information, Z scores were calculated and are reported in the table below. All z scores except for the value of skeweness for the female non-hacker sample, did not reach the 1.96 level of significance indicating a deviation from normality (see Appendix C, table C1).
Tests of normality showed all four p-values above the significance level of p=.05 for the novel scale, pointing to lack of significant deviations from a normal distribution. For the SQ not all p-values were above .05 (see Appendix C, table C2).

(3) Homogeneity of Variance. Levene's test (untrasformed) showed equal variances for gender in the SQ-R, $F(1,158) = .575$, $p=.559$, and in the novel item scale $F(1,158)=.822$, $p=.366$; and for hackers vs. non-hackers in the SQ-R, $F(1,158)=.551$, $p=.459$ and in the novel scale $F(1,158)=1.302$, $p=.256$.

A final look at the QQ plots and histograms (see Appendix C, figures C1-C4) shown that the only distribution that approximated to a normal one was the male/hackers for both measures. All the other distributions showed a clear deviation from normality. On the basis of all of the above considerations, non-parametric tests were chosen.

4.4.3 Score comparisons between groups

The time spent on hacking activities had significant positive correlations with the SQ-R (Rho=.212, $p<.01$) and with the novel scale (Rho=.170, $p<.05$) however when applying

Bonferroni-Holm correction[15] for multiple comparisons (new minimum level of threshold, p=.025) the correlation with the novel scale was not significant anymore.

As expected, significant differences were found between hackers and non-hackers in the time spent hacking, U=176, z=-11.453, p=.000, r=.9 large effect.

A Mann-Whitney test revealed an effect of gender in both the SQ-R (U=2447, z= -2.45 p<.05, r=- .19, small effect) and the novel scale (U=2428, z=-2.52, p<.05, r= -.20, small effect), with males scoring higher than females in both questionnaires.

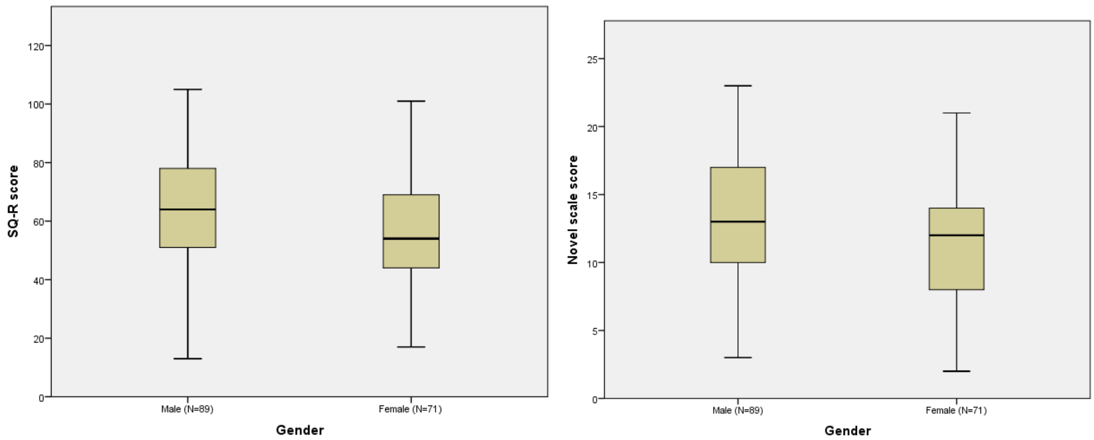

Figure 4.1 Box and whisker plots showing min, median, max and IQR for males and females in the SQ-R scores and novel scale scores.

Hackers scored higher than non-hackers on the SQ-R (see section 4.4.1 for descriptive statistics) and a Mann-Whitney test revealed that the difference was significant (U=2407.5, z= = -2.315, p=.021, r=.18, small effect). Also on the novel scale hackers showed higher scores than non-hackers (see section 4.4.1 for descriptive statistics) but the difference was not significant (U=2645.5, z = - 1.489, p=.137).

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15 [illegible] +1

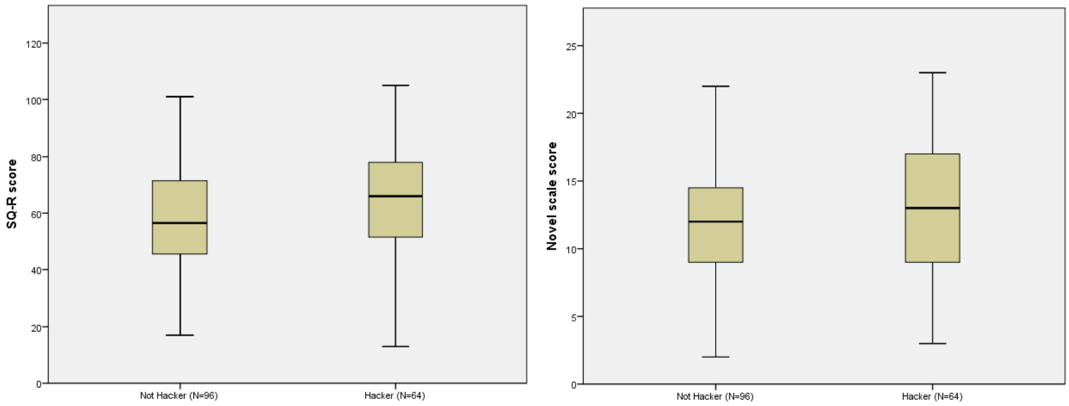


Figure 4.2 Box and whisker plots showing min, median, max and IQR for hackers and non-hackers in the SQ-R scores and novel scale scores.

To further probe the hypothesis of a connection between hacking and both SQ-R and the novel scale, non-parametric bivariate correlations between questionnaire scores and the percentage of time spent on hacking activities were also investigated. It was found that time spent on hacking correlated significantly with SQ-R (Rho =.212, p<.01) and with the novel scale (Rho =.170, p<.05); the latter significance however did not survive after application of a Bonferroni-Holm correction for multiple comparisons (new minimum level of threshold: p=.025).

A series of Mann-Whitney U tests was conducted to look at the discriminative items of the SQ-R between hackers and non-hackers, and the result is reported in the table below. In bold are items in which hackers scored higher than non-hackers. After applying a Bonferroni-Homs correction the minimum level of threshold decreased to .0006 and the only items that remained significant are underlined.

Table 4.4 Discriminative items of the SQ-R between hackers and non-hackers in the total sample.

Table 4.4

Discriminative items of the SQ-R between hackers and non-hackers in the total sample. Reverse-scored items are indicated with an asterisk (*). In bold are items in which hackers scored higher than non-hackers.

ITEM	Test Statistic	Hackers	Non Hackers
1 I find it very easy to use train timetables, even if this involves several connections	U = 2439.0 Z = -2.539 p = .011	Mean = 1.56 (s.e.=.070) Median =2 SD = .560	Mean = 1.26 (s.e=. 0.75) Median =1 SD = .740
2 I like music or books shops because they are	U= 2541.000	Mean = .94	Mean = 1.19 (s.e.

clearly organized	Z= -2.094 p= .036	(s.e.=.091) Median =1 SD =.732	=.074) Median = 1.00 SD = .726
<u>*6 I find it difficult to read and understand maps</u>	U= 1791.000 Z= -4.868 p= .000	Mean = 1.58 (s.e.=.077) Median = 2 SD = .612	Mean = .92 (s.e.=.086) Median =.00 SD =.850
***8 I am not interested in the details of exchange rates, interest rates, stock and shares**	U= 2376.500 Z= -2.895 p= .004	Mean = .70 (s.e.=.094) Median =1 SD =.749	Mean = .39 (s.e.=.066) Median =1 SD =.654
9 If I were buying a car, I would want to obtain specific information about its engine capacity	U= 2441.000 Z= -2.331 p= .020	Mean = 1.17 (s.e.=.107) Median =1 SD =.808	Mean = .86 (s.e.=.082) Median =1 SD =.803
***10 I find it difficult to learn how to programme video recorders**	U= 2162.000 Z= -3.469 p= .001	Mean = 1.41 (s.e.=.091) Median =2 SD = .729	Mean = .96 (s.e.=.081) Median =.00 SD =.803
<u>*17 I am not interested in understanding how wireless communication works</u>	U= 1371.500 Z= -6.365 p= .000	Mean = 1.58 (s.e.=.080) Median =2 SD =.638	Mean = .71 (s.e.=.080) Median =1 SD =.790
20 Whenever I run out of something at home, I always add it to a shopping list	U= 2344.500 Z= -2.766 p= .006	Mean = .43 (s.e.=.084) Median =.00 SD =.665	Mean = .81 (s.e.=.088) Median =.50 SD = .870
23 I am interested in my family tree and in understanding how everyone is related to each other in the family	U= 2318.000 Z= -2.890 p= .004	Mean = .73 (s.e.=.100) Median =1 SD =.802	Mean = 1.09 (s.e.=.075) Median = 1 SD = .737
24 When I learn about historical events, I do not focus on exact dates	U= 2515.000 Z= -2.371 p=.018	Mean = .33 (s.e.=.074) Median =.00 SD =.592	Mean = .57 (s.e.=.070) Median =.00 SD =.691
<u>25 I find it easy to grasp exactly how odds work in betting</u>	U= 2050.500 Z= -4.027 p= .000	Mean = .97 (s.e.=.104) Median =1 SD =.835	Mean = .45 (s.e.=.070) Median =.00 SD =.693
***26 I do not enjoy games that involve a high degree of strategy**	U= 2466.000 Z= -2.356 p= .018	Mean = 1.34 (s.e.=.090) Median =1 SD =.718	Mean = 1.04 (s.e.=.081) Median =1 SD =.803
31 At home, I do not carefully file all important documents	U= 2428.000 Z= -2.512 P= .012	Mean = .69 (s.e.=.107) Median =.00 SD =.852	Mean = 1.04 (s.e.=.089) Median =1 SD =.877
32 I am fascinated by how machines work	U= 1400.000 Z= -6.191 p= .000	Mean = 1.41 (s.e.=.091) Median =2 SD =.729	Mean = .58 (s.e.=.072) Median =.00 SD =.706
36 If someone stops to ask me the way, I'd be able to give directions to any part of my home town	U= 2484.500 Z= -2.283 p= .022	Mean = 1.30 (s.e.=.094) Median =1 SD =.749	Mean = 1.01 (s.e.=.080) Median =1 SD = .784
<u>43 If there was a problem with the electrical wiring in my home, I'd be able to fix it myself</u>	U= 1643.500 Z= -5.894 p= .000	Mean = .94 (s.e.=.102) Median = 1 SD = .814	Mean = .25 (s.e.=.057) Median =.00 SD =.560
<u>*45 I rarely read articles or webpages about new technology</u>	U= 1830.000 Z= -4.679 p= .000	Mean = 1.38 (s.e.=.103) Median =2 SD =.826	Mean = .73 (s.e.=.078) Median =1 SD =.771
49 I do not tend to remember people's birthdays (day/month)	U= 2386.500 Z= -2.644 p= .008	Mean = .69 (s.e.=.099) Median =.00	Mean = 1.05 (s.e.=.087) Median = 1

		SD =.794	SD = .858
***51 I find it difficult to understand information the bank sends me on different investment and saving systems**	U= 2461.500 Z= -2.378 p= .017	Mean = 1.03 (s.e.=.094) Median =1 SD =.755	Mean = .74 (s.e.=.075) Median =2 SD = .740
52 If I were buying a camera, I would not look carefully into the quality of the lens	U= 2409.000 Z= -2.615 p= .009	Mean = 1.48 (s.e.=.092) Median =2 SD = .734	Mean = 1.18 (s.e.=.079) Median =1 SD =.777
53 If I were buying a computer, I would want to know exact details about its hard drive capacity and processor speed	U= 1900.500 Z= -5.132 p= .000	Mean = 1.91 (s.e.=.043) Median =2 SD = .344	Mean = 1.30 (s.e.=.086) Median =.00 SD = .844
56 I do not follow any particular system when I am cleaning at home	U= 2412.500 Z= - 2.615 p= .009	Mean = .48 (s.e.=.086) Median =.00 SD =.690	Mean = .81 (s.e.=.082) Median =1 SD =.808
***58 I am not very meticulous when I carry out D.I.Y. or home improvements**	U= 2512.000 Z= -2.018 p= .044	Mean = 1.17 (s.e.=.105) Median = 1 SD = .834	Mean = .90 (s.e.= .086) Median = 1 SD = .848
60 If I were buying a stereo, I would want to know about its precise technical features	U= 1847.500 Z= -4.622 p= .000	Mean = 1.45 (s.e.=.094) Median = 2 SD = .754	Mean = .82 (s.e.=.083) Median =.00 SD = .817
66 In maths, I am intrigued by the rules and patterns governing numbers	U= 2266.000 Z= -3.202 p= .001	Mean = .91 (s.e.=.101) Median = 1 SD =.811	Mean = .52 (s.e.=.078) Median = .00 SD = .765
68 I could list my favourite 10 books, recalling titles and authors names from memory	U= 2410.500 Z= -2.640 p= .008	Mean = .86 (s.e.=.107) Median=.00 SD=.852	Mean = 1.12 (s.e.=.091) Median= SD=.893

According to the analysis, discriminative items in which hackers scored higher refer mostly to an interest in technology, in topography and in mathematics. Discriminative items in which non-hackers scored higher pertain mainly to domestic domains and to the tendency to remember things related to birthdays or books. To check whether this pattern was due to the gender imbalance between hackers and non-hackers (hackers: males=56, females=8; non-hackers: males=33, females=74), discriminative items between males and females were investigated and are reported in the table below; items in bold are those in which males scored higher than females, those underlined are items that remained significant even after having applied Bonferroni-Holm correction.

Table 4.5 Discriminative items of the SQ-R between males and females in the total sample.

Table 4.5

Discriminative items of the SQ-R between males and females in the total sample. Reverse-scored items are indicated with an asterisk (*). Items in bold are those in which males scored higher than females.

ITEM	Test Statistic

***6 I find it difficult to read and understand maps**	U= 1410.500 Z=-6.442 p=.000
***8 I am not interested in the details of exchange rates, interest rates, stock and shares**	U= 2652.000 Z=-2.005 p=.045
9 If I were buying a car, I would want to obtain specific information about its engine capacity	U= 2392.500 Z=-2.659 p=.008
***10 I find it difficult to learn how to programme video recorders**	U= 2177.500 Z=-3.598 p=.000
***V15 I find it difficult to understand instruction manuals for putting appliances together**	U= 2310.500 Z=-3.259 p=.001
***17 I am not interested in understanding how wireless communication works**	U= 1801.500 Z=-4.961 p=.000
20 Whenever I run out of something at home, I always add it to a shopping list	U= 1949.000 Z=-4.542 p=.000
23 I am interested in my family tree and in understanding how everyone is related to each other in the family	U= 2089.000 Z=-3.914 p=.000
25 I find it easy to grasp exactly how odds work in betting	U= 2209.500 Z=-3.606 p=.000
***26 I do not enjoy games that involve a high degree of strategy**	U= 2156.000 Z=-3.688 p=.000
*28 I do not find it distressing if people who live with me upset my routines	U= 2319.500 Z=-3.103 p=.002
30 I can remember large amounts of information about a topic that interests me	U= 2529.000 Z=-2.217 p=.027
31 At home, I do not carefully file all important documents	U= 2492.000 Z=-2.465 p=.014
32 I am fascinated by how machines work	U= 1459.000 Z=-6.106 p=.000
***33 When I look at a piece of furniture, I do not notice the details of how it was constructed**	U= 2407.500 Z=-2.801 p=.005
***35 I do not tend to watch science documentaries on television or read articles about science and nature**	U= 2377.000 Z=-2.869 p=.004
*37 When I look at a painting, I do not usually think about the technique involved in making it	U= 2551.500 Z=-2.315 p=.021
43 If there was a problem with the electrical wiring in my home, I'd be able to fix it myself	U= 2026.500 Z=-4.559 p=.000
44 My clothes are not carefully organised into different types in my wardrobe	U= 2487.000 Z=-2.505 p=.012
***45 I rarely read articles or webpages about new technology**	U= 1744.500 Z=-5.166 p=.000
46 I can easily visualise how the motorways in my region link up	U= 2504.000 Z=-2.665 p=.008
49 I do not tend to remember people's birthdays (day/month)	U= 2579.000 Z=-2.126 p=.034

***51 I find it difficult to understand information the bank sends me on different investment and saving systems**	U= 2617.500 Z= -1.997 p=.046
***52 If I were buying a camera, I would not look carefully into the quality of the lens**	U= 2576.500 Z=-2.179 p=.029
53 If I were buying a computer, I would want to know exact details about its hard drive capacity and processor speed	U= 1867.500 Z=-5.503 p=.000
55 When I get to the checkout at a supermarket I pack different categories of goods into separate bags	U= 2517.000 Z=-2.431 p=.015
*56 I do not follow any particular system when I am cleaning at home	U= 2386.000 Z=-2.905 p=.004
*57 I do not enjoy in-depth political discussion	U= 2627.000 Z=-1.988 p=.047
***58 I am not very meticulous when I carry out D.I.Y. or home improvements**	U= 2605.000 Z=-1.881 p=.060
60 If I were buying a stereo, I would want to know about its precise technical features	U= 1944.500 Z=-4.445 p=.000
*65 It does not bother me if things in the house are not in their proper place	U= 2503.000 Z=-2.411 p=.016
66 In maths, I am intrigued by the rules and patterns governing numbers	U= 2288.500 Z=-3.304 p=.001
***67 I find it difficult to learn my way around a new city**	U= 2590.000 Z=-2.095 p=.036
69 When I read the newspaper, I am drawn to tables of information, such as football league scores or stock market indices	U= 2510.000 Z=-2.973 p=.003
***70 When I am in a plane, I do not think about the aerodynamics**	U= 2393.500 Z=-2.863 p=.004
72 When I have a lot of shopping to do, I like to plan which shops I am going to visit and in what order	U= 2613.500 Z=-1.990 p=.047
75 I could generate a list of my favourite 10 songs from memory, including the title and the artist's name who performed each song	U= 2318.500 Z=-3.093 p=.002

The same pattern found for the differences in the hacking condition (hackers vs. non-hackers) was found when comparing males and females. It was clear that the discriminative items found in the previous analyses could be mediated by a gender effect. In a third analysis then discriminative items were analysed controlling for sex.

When taking into account only the male sample, there were no significant differences in the total SQ-R, U=917. Z=-.059, p=.953 and in the novel scale, U=910.5, z=-.115, p=.909 between hackers and non-hackers. Looking into differences in items responses between hackers and non-hackers within the male sample, only ten items still showed significant differences (see table below). However, after applying Bonferroni-Holm correction (minimum level of threshold p=.0006), only item 43 (“If there was a problem with the electrical wiring in my home, I'd be able to fix it myself”) still remained significant.

Items in which hackers scored higher (in bold) are: 1) “I find it very easy to use train timetables, even if this involves several connections”; 8) “I am not interested in the details of exchange rates, interest rates, stock and shares” (reverse scored); 17) “I am not interested in understanding how wireless communication works” (reverse scored); 32) “I am fascinated by how machines work”; 43) “If there was a problem with the electrical wiring in my home, I'd be able to fix it myself”; 53) “If I were buying a computer, I would want to know exact details about its hard drive capacity and processor speed”. Items in which non-hackers scored higher are: 2) “I like music or books shops because they are clearly organized”; 24) “When I learn about historical events, I do not focus on exact dates” (reverse scored); 41) “I am interested in knowing the path a river takes from its source to a sea”; 48) “I do not particularly enjoy learning about facts and figures in history” (reverse scored).

Table 4.6 Discriminative items of the SQ-R between hackers and non-hackers only within the male sample.

Table 4.6

Discriminative items of the SQ-R between hackers and non-hackers only within the male sample. Reverse-scored items are indicated with an asterisk (*). In bold are items where hackers scored higher than non-hackers.

ITEM	Test Statistic	Hackers	Non Hackers
1 I find it very easy to use train timetables, even if this involves several connections	U = 697.000 Z = -2.162 p = .031	Mean = 1.57 (s.e.=.076) Median =2 SD = .568	Mean = 1.21 (s.e=. 136) Median =1 SD = .781
2 I like music or books shops because they are clearly organized	U= 628.000 Z= -2.701 p= .007	Mean = .89 (s.e.=.098) Median =1 SD =.731	Mean = 1.33 (s.e. =.120) Median = 1 SD = .692
***8 I am not interested in the details of exchange rates, interest rates, stock and shares**	U= 646.500 Z= -2.617 p= .009	Mean = .77 (s.e.=.102) Median =1 SD =.763	Mean = .36 (s.e.=.144) Median =.00 SD =.653
***17 I am not interested in understanding how wireless communication works**	U= 572.000 Z= -3.302 p= .001	Mean = 1.57 (s.e.=.084) Median =2 SD =.628	Mean = 1.00 (s.e.=.144) Median =1 SD =.829
*24 When I learn about historical events, I do not focus on exact dates	U= 720.000 Z= -2.013 p=.044	Mean = .38 (s.e.=.083) Median =.00 SD =.620	Mean = .67 (s.e.=.128) Median =1 SD =.736
32 I am fascinated by how machines work	U= 672.000	Mean = 1.41	Mean = 1.03

	Z= -2.317 p= .020	(s.e.=.098) Median =2 SD =.733	(s.e.=.134) Median =1 SD =.770
41 I am interested in knowing the path a river takes from its source to a sea	U= 721.500 Z= -2.072 p= .038	Mean = .29 (s.e.=.066) Median =.00 SD =.494	Mean = .61 (s.e.=.130) Median =.00 SD = .747
43 If there was a problem with the electrical wiring in my home, I'd be able to fix it myself	U= 529.000 Z= -3.635 p= .000	Mean = .98 (s.e.=.107) Median = 1 SD = .798	Mean = .36 (s.e.=.122) Median =.00 SD =.699
*48 I do not particularly enjoy learning about facts and figures in history	U= 666.000 Z= -2.325 p= .020	Mean = .82 (s.e.=.108) Median =1 SD =.811	Mean = 1.24 (s.e.=.138) Median =1 SD =.792
53 If I were buying a computer, I would want to know exact details about its hard drive capacity and processor speed	U= 791.500 Z= -1.970 p= .049	Mean = 1.91 (s.e.=.046) Median =2 SD = .345	Mean = 1.70 (s.e.=.111) Median =2 SD = .637

A Mann-Whitney test was carried out to look for significant differences in the novel scale items in the total sample between hackers and non-hackers. Only three items showed significant differences and are reported in the table below; hackers scored higher on items 5 and 9, while non-hackers scored higher on item 11. After applying Bonferroni-Holm correction however none of the three items reached the significance level of .0038.

Table 4.7 Discriminative items of the novel scale between hackers and non-hackers in the total sample

Table 4.7

Discriminative items of the novel scale between hackers and non-hackers in the total sample

ITEM	Test Statistic	Hackers	Non Hackers
5. I believe that no matter what life throws at me, I will be able to handle it	U = 2528.5 Z = -2.025 p = .043	Mean = 1.30 (s.e.=.101) Median =1 SD = .810	Mean = 1.06 (s.e.=.075) Median =1 SD = .737
9 I am good at finding solutions to problems that other would not be able to solve	U = 2536.000 Z = -2.122 p = .034	Mean = 1.13 (s.e.=.093) Median =1 SD = .745	Mean = .88 (s.e=.071) Median =1 SD = .696
11 I have been told I am a creative person	U= 2405.000 Z= -2.565 p= .010	Mean = .72 (s.e.=.093) Median =1 SD =.745	Mean = 1.06 (s.e. =.085) Median = 1 SD = .839

When considering only the male sample, only one item showed significant differences between hackers and non-hackers – item 11 U=628.000, z=-2.691, p=.007, but failed to reach the significance level of .0038 after having applied a Bonferroni-

Holm correction. Specifically, hackers (mean=.64, s.e.=.097, median=.50, SD=.724) scored lower than non-hackers (mean=1.12, s.e. = .143, median=1, SD=.820).

4.4.4 Principal Component Analyses

4.4.4.1 **PCA on the novel scale**

A Principal Component Analysis (PCA) was conducted on the novel scale with oblique rotation (promax) to obtain Eigenvalues for each component in the data. At first inter correlations between items were analysed to check the pattern of relationships. Item 13 did not correlate with any other item, and items 6, 8 and 11 correlated just with one other item in the scale. Item 6 correlated with item 3 (Rho= .310); item 8 correlated with item 10 (Rho = .302); item 11 correlated with item 3 (Rho = .316)

KMO measure of sampling adequacy (.807) was considered to be great (Field, 2009, p. 659), Bartlett's Test of Sphericity was significant (Chi-Square (78) =.376,657, p=.000) and all the diagonal elements of the anti-image correlation matrix were well above 0.5. These values represent the KMO values of sampling adequacy for each variable, confirming the adequacy of the sample.

Four components were extracted with Eigenvalues over Kaiser's criterion of 1 and in combination explained 55% of the variance in the data. The first component explained most of the variance (28%), the second explained 9.7 %, the third 8.86 % and the fourth 7.87% of the variance.

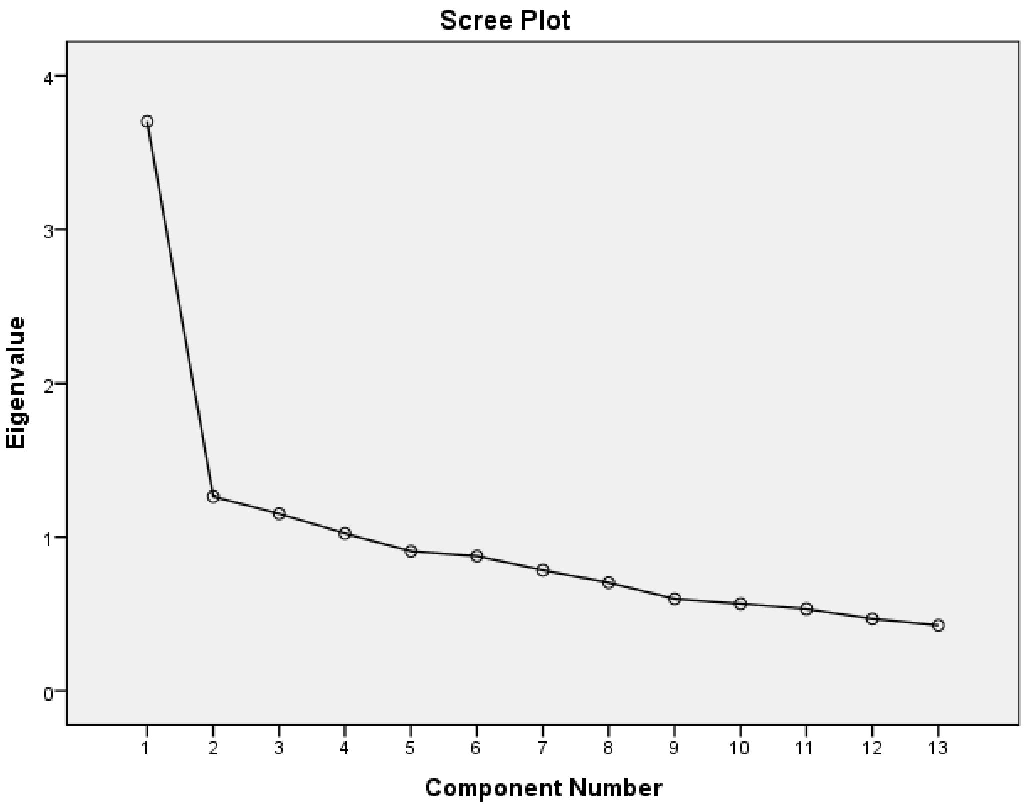


Figure 4.3 Screeplot of components in the novel scale

Pattern matrix and structure matrix were analysed together to interpret the component structure (see tables 4.8 and 4.9)

Table 4.8 Pattern matrix of the novel scale items.

Table 4.8

Pattern Matrix

Items	Component 1	Component 2	Component 3	Component 4
When I encounter a problem, I usually look at it from different perspectives in order to come up with the best solution	.745	-.155	.050	-.025
I have been told I am a creative person	.646	.004	-.110	-.167
I believe that no matter what life throws at me, I will be able to handle it	.569	-.073	-.018	.356
I like trying new things	.567	.363	-.258	.119
*I do not like learning new things	.421	.271	.265	-.285
*I do not think it is necessary to come up with new solutions to a problem if the one I've used in the past was successful	-.014	.784	.183	.145
*When I find a way to solve a situation I do not feel the curiosity to find another way to solve it	-.154	.775	.144	-.038
*I do not feel comfortable with taking new perspectives into things	.234	.497	.185	-.001
*I often get stuck and ask other for help	-.195	.042	.865	-.089
I am good at finding solutions to problems that other would not be able to solve	.329	.250	.523	.205
I would define myself as a type of person who thinks 'outside the box'	.381	.057	.464	.008
*I feel uncomfortable in taking snap decisions	-.015	.030	-.123	.846
*I am afraid of making a mistake and usually this affects the decision I make	-.240	.192	.396	.561

Extraction Method: Principal Component Analysis
Rotation Method: Promax with Kaiser Normalization
a. Rotation converged in 6 iterations

Table 4.9 Structure matrix of the novel scale items.

Table 4.9

Structure Matrix

Items	Component 1	Component 2	Component 3	Component 4
When I encounter a problem, I usually look at it from different perspectives in order to come up with the best solution	.704	.122	.300	.156
I believe that no matter what life throws at me, I will be able to handle it	.631	.198	.288	.489
I like trying new things	.622	.508	.121	.276
I have been told I am a creative person	.558	.166	.112	-.023
*I do not like learning new things	.550	.447	.448	-.045
*When I find a way to solve a situation I do not feel the curiosity to find another way to solve it	.171	.758	.316	.117
*I do not think it is necessary to come up with new solutions to a problem if the one I've used in the past was successful	.230	.751	.099	.253
*I do not feel comfortable with taking new perspectives into things	.488	.639	.439	.213
*I often get stuck and ask other for help	.151	.229	.774	.099
I would define myself as a type of person who thinks 'outside the box'	.594	.342	.641	.246
*I I am good at finding solutions to problems that other would not be able to solve	.510	.075	.634	.382
I feel uncomfortable in taking snap decisions	.172	.158	.106	.815
*I am afraid of making a mistake and usually this affects the decision I make	.142	.347	.509	.642

Extraction Method: Principal Component Analysis
Rotation Method: Promax with Kaiser Normalization
a. Rotation converged in 6 iterations

In the structure matrix lots of items loaded in different components, but this is because it takes into account the shared variance of factors between components and components 1, 2 and 3 are correlated with each other (see table 4.10)

Table 4.10 Components correlation matrix

Table 4.10

Correlation matrix of the components extracted

Component	1	2	3	4
1	-	-	-	-
2	.357	-	-	--
3	.410	.317	-	-
4	.268	.204	.267	-

As it was clear from the correlation matrix, items 13 and 8 loaded on to a fourth component separated from the others. The fourth component itself did not correlate with the other three suggesting that it might be useful to remove items 13 and 8 from the scale, which aims to represent a cohesive measure. Components 1, 2 and 3 seem to correlate fairly well with each other. The structure that emerged is interpreted in the table 4.11.

Table 4.11 Component structure interpretation

Table 4.11
Component structure interpretation

RESOURCEFULNESS/CURIOSITY	PROBLEM SOLVING	INVENTIVENESS	INTUITION/SELF-CONFIDENCE
7: When I encounter a problem, I usually look at it from different perspectives in order to come up with the best solution	2: I do not think it is necessary to find new solutions to a problem, if the one I have used in the past was successful	6:I often get stuck and ask other for help	13: I feel comfortable in taking snap decisions
11: I have been told I am a creative person	12: When I find a way to solve a situation I do not feel the curiosity to find another way to solve it	3: I would define myself as a type of person who thinks outside the box	8: I am afraid of making a mistake and usually this affects the decision I make
5: I believe that no matter what life throws at me, I will be able to handle it	10: I do not feel comfortable with taking new perspectives into things	9: I am good at finding solutions to problems that other would not be able to solve	
1: I like trying new things 4: I do not like learning new things			

A reliability analysis showed a good internal consistency of the scale (Cronbach's Alpha =.778). However, the removal of item 11 and 13 would increase the value to .779 further supporting the decision to remove them from the final scale. The removal of all other items would not increase the reliability of the scale. A reliability analysis without items 11 and 13 increased the value of Cronbach's Alpha to .779 (see table 4.12).

Table 4.12 Item-total statistics

Table 4.12

Item-Total statistics

Item	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Chronbach's Alpha if Item Deleted
1. I like trying new things	10.99	21.119	.465	.759
2. I do not think it is necessary to come up with new solutions to a problem if the one I have used in the past was successful	11.93	21.285	.364	.768
3. I would define myself as a type of person who thinks outside the box	11.49	19.987	.567	.747
4. I do not like learning new things	10.82	21.520	.443	.762
5. I believe that no matter what life throws at me, I will be able to handle it	11.30	20.501	.463	.758
6. I often get stuck and ask other for help	11.91	21.834	.327	.771
7. When I encounter a problem, I usually look at it from different perspectives in order to come up with the best solution	11.28	21.006	.402	.764
8. I am afraid of making a mistake and usually this affects the decision I make	11.81	21.021	.384	.766
9. I am good at finding solutions to problems that other would not be able to solve	11.48	20.842	.447	.760
10. I do not feel comfortable with taking new perspectives into things	11.34	20.489	.535	.752
11. I have been told I am a creative person	11.53	21.622	.269	.779
12. When I find a way to solve a situation I do not feel the curiosity to find another way to solve it	11.95	21.595	.373	.767
13. I feel uncomfortable in taking snap decisions	11.66	21.747	.265	.779

As result from this first PCA, some problematic items were found. Item 13 did not correlate with any other item, it loaded on to one component with just item 8 and if deleted, reliability increased. Item 11 correlated just with item 3 and its removal increased reliability of the scale. Item 8 showed just one correlation with item 10 and item 6 correlated only with item 3. Field (2009) suggests that if any variables have lots of correlations below .3 it has to be considered to exclude them. This was certainly the case of item 13, item 11, item 8 and item 6.

4.4.4.2 **PCA on the novel scale without items 6, 8, 11, 13**

Another PCA with promax rotation was conducted without items 6, 8, 11 and 13. Two components were extracted with Eigenvalues above 1. The first accounted for 35 % of the variance, the second for the 13%. Altogether the variance explained was 50%.

Pattern and structure matrices were analysed together to interpret the components structure (see tables 4.13, 4.14)

Table 4.13 Pattern Matrix

Table 4.13

Pattern matrix

Items	**Component**	
	1	**2**
9. I am good at finding solutions to problems that other would not be able to solve	.776	-.174
7. When I encounter a problem, I usually look at it from different perspectives in order to come up with the best solution	.739	-.110
5. I believe that no matter what life throws at me, I will be able to handle it.	.680	-.043
3. I would define myself as a type of person who thinks outside the box	.634	.117
4. I do not like learning new things	.442	.277
1. I like trying new things	.381	.362
2. I do not think it is necessary to come up with new solutions to a problem if the one I have used in the past was successful	-.163	.830
12. When I find a way to solve a situation I do not feel the curiosity to find another way to solve it	-.115	.796
10. I do not feel comfortable with taking new perspectives into things	.306	.522

Table 4.14 Structure Matrix

Table 4.14

Structure matrix

Items	Component	
	1	2
9. I am good at finding solutions to problems that other would not be able to solve	.703	.151
7. When I encounter a problem, I usually look at it from different perspectives in order to come up with the best solution	.692	.198
3. I would define myself as a type of person who thinks outside the box	.683	.382
5. I believe that no matter what life throws at me, I will be able to handle it.	.662	.241
4. I do not like learning new things	.558	.461
1. I like trying new things	.532	.521
2. I do not think it is necessary to come up with new solutions to a problem if the one I have used in the past was successful	.183	.761
12. When I find a way to solve a situation I do not feel the curiosity to find another way to solve it	.218	.748
10. I do not feel comfortable with taking new perspectives into things	.525	.650

Both components correlated well with each other (.418). The final component structure is reported in the table 4.15.

Table 4.15 Component structure interpretation

Table 4.15

Component structure interpretation for the novel scale after exclusion of items 6, 8, 11 and 13.

RESOURCEFULNESS	PROBLEM SOLVING
N_9 I am good at finding solutions to problems that other would not be able to solve	2: I do not think it is necessary to find new solutions to a problem, if the one I have used in the past was successful
N_7 When I encounter a problem, I usually look at it from different perspectives in order to come up with the best solution	12: When I find a way to solve a situation I do not feel the curiosity to find another way to solve it
N_5 I believe that no matter what life throws at me, I will be able to handle it	10: I do not feel comfortable with taking new perspectives into things
N_3 I would define myself as a type of person who thinks outside the box	
N_4 I do not like learning new things	
N_1 I like trying new things	

To further investigate the scale properties, a reliability analysis was then conducted. Cronbach's alpha reveals a good internal consistency of the 9 items scale (.764).

Contrary to the previous analysis with all the items of the novel scale in which no significant differences were found between hackers and non-hackers, a significant difference was found in their total scores with this 9-item version of the scale, U=2346, z=-2.396, p=.017, r=.15, small effect. Specifically, hackers scored higher (mean=10.36, SD=3.83) than non-hackers (mean=8.93, SD=3.58). Nevertheless, when considering only the male sample the difference was not significant, U=867.5, z=-.346, p=.729.

Whereas the previous correlation between the time spent hacking and the original version of the novel scale (Rho = .170, p=.032) was not significant (indeed it did not pass the Bonferroni-corrected threshold), the correlation with the 9-item version of the scale appears larger in size and is significant (Rho=.230, p=.003).

4.4.4.3 **Combined PCAs of SQ-R and the Novel scale**

Several PCAs with promax rotation were conducted with all items of the SQ-R and the novel scale – either the 13 item version and the 9 item version. Also, a PCA was conducted with all items of the novel scale and the summed score of the SQ-R. The PCAs showed that the items of the novel scale aggregated together independently from the items of the SQ-R. (see appendix C, table C3).

Another PCA with promax rotation was conducted on the SQ-R summed score and the 9-item version of the novel scale. The aim was to investigate whether the novel scale measured constructs not already covered by the SQ-R. Two components were extracted and together accounted for almost 50% of the variance. The first component accounted for the 35% and the second accounted for the 13% of the variance.

Table 4.16 Pattern matrix of the 9 items novel scale and the SQ total score

Table 4.16

Pattern matrix of the 9 items novel scale and the SQ total score

Item	**Component**	
	1	**2**
9. I am good at finding solutions to problems that other would not be able to solve	.747	
7. When I encounter a problem, I usually look at it from different perspectives in order to come up with the best solution	.739	

SQ_R score	.680	
5. I believe that no matter what life throws at me, I will be able to handle it.	..655	
3. I would define myself as a type of person who thinks outside the box	.643	
4. I do not like learning new things	.447	
2. I do not think it is necessary to come up with new solutions to a problem if the one I have used in the past was successful		.830
12. When I find a way to solve a situation I do not feel the curiosity to find another way to solve it		.789
10. I do not feel comfortable with taking new perspectives into things		.551
1. I like trying new things	.303	.411

Table 4.17 Structure Matrix of the 9 items novel scale and the SQ total score

Table 4.17

Structure Matrix of the 9 items novel scale and the SQ total score

Item	Component	
	1	2
SQ_R score	.697	.336
3. I would define myself as a type of person who thinks outside the box	.691	..391
7. When I encounter a problem, I usually look at it from different perspectives in order to come up with the best solution	.690	
9. I am good at finding solutions to problems that other would not be able to solve	.676	
5. I believe that no matter what life throws at me, I will be able to handle it.	.644	
4. I do not like learning new things	.567	.470
2. I do not think it is necessary to come up with new solutions to a problem if the one I have used in the past was successful		.754
12. When I find a way to solve a situation I do not feel the curiosity to find another way to solve it		.739
10. I do not feel comfortable with taking new perspectives into things	.497	.662
1. I like trying new things	.482	.543

The component structure was clearly similar to the one obtained only analysing the 9 items novel scale, with the total score of the SQ-R loading on to the first component – resourcefulness - . Differently from the previous analysis, item 1 had the highest loading on to component 2 even if a large amount of its variance is shared with component 1. The two components were well correlated together (r=.436).

The correlation between the aggregated total scores of the SQ-R and the novel scale-r and the time spent hacking was significant (Rho=.223, p=.005).

Considering the total score of the SQ-R and the total score on the 9-item novel scale aggregated together, there was a significant difference between hackers and non-hackers, U=2358.5, Z=-2.344, p=.019, r=.18 small effect; hackers scored higher (mean=75.24, SD=20.38) than non-hackers (mean=60.01, SD=22.12). When the analysis was conducted only with the male sample, the difference was not significant, U=910, z=-.119, p=.905.

However, the two scales together appeared to improve very slightly the discriminative value of the SQ-R alone (U=2407.5, z= = -2.315, p=.021, r=.18, small effect).

4.5 Discussion

This first study was an explorative one and aimed at (1) looking at the distribution of systemizing traits in a sample of hackers compared with non-hackers and (2) pilot testing a novel scale and assessing whether any differences in scores emerge between hackers and non-hackers. The main hypothesis was that hackers have a drive to systemize, strong problem solving skills and creativity traits and this will result in higher scores on the SQ-R and on the novel scale compared to the general population. The first hypothesis was partially supported by the findings, as hackers scored higher than non-hackers on the SQ-R when analysis was made on the total sample. However when considering only the male sample no differences were found. This result was obtained despite having used the SQ-R, which is a revised version of the original SQ specifically developed to avoid a bias towards systemizing domains that are typically male. Sex differences in the SQ-R were also found and this is consistent with the literature (Wheelwright et al., 2006). Differences between hackers and non-hackers were also investigated at the item level, first with the total sample and then just with males as the distribution of sexes was unbalanced between groups. Indeed, there were more males in the hackers sample and more females in the non-hackers sample, given that the majority of this latter group were psychology students. Within the total sample, discriminative items were mostly related with interests and skills in technology (i.e. “If there was a problem with the electrical wiring in my home, I'd be able to fix it myself"; "I am fascinated by how machines work"; "If I were buying a computer, I would want to know exact details about its hard drive capacity and processor speed") and topography (i.e. "If someone stops to ask me the way, I'd be able to give directions to any part of my home town", "1 I find it very easy to use train timetables, even if this involves several connections") and this remained true also when considering only the male sample. After applying Bonferroni –Holm correction for multiple comparisons, the only item that still remained significant was item 43) "If there was a problem with the electrical wiring in my home, I'd be able to fix it myself" in which hackers scored higher than non-hackers.

The second aim was to pilot test the novel scale developed ad hoc to target specific traits of the hacking mind-set. Considering all 13 items of the scale, there was no significant difference between hackers and non-hackers, but after removing four problematic items (6, 8, 11, and 13) based on an exploratory PCA, the scale shown to be discriminative between the two groups. Moreover, two clear and distinctive components emerged from the analysis – resourcefulness/curiosity and problem solving. Items from the SQ-R and the novel scale were analysed together, as well as SQ total score and novel scale items, and the results confirmed that the novel scale measured in fact different constructs than the ones measured by the SQ-R. The aggregated scores of SQ-R and the 9-item novel scale appeared to be slightly more discriminative than the SQ-R alone. However, it has to be noted that when considering the male sample only, there were no significant differences between hackers and non-hackers; although both scales and their aggregated scores had a positive significant correlation with time spent on hacking activities.

As a result from these analyses, the final version of the novel scale that was used in Study 2 and Study 3 described in the following chapters did not comprise items 6, 8, 11 and 13.

Study 1 was a preliminary investigation of the distribution of systemizing traits within the hackers group and between hackers and non-hackers; it was also the testing stage of the novel scale I developed ad hoc to assess creativity and problem solving. Results found demonstrated that indeed there was a difference in the distribution of the systemizing traits between hackers and non-hackers but the difference was mediated by sex. In fact, when analysing only the male sample, the difference was not significant anymore. The following step was Study 2. In Study 2 the investigation moved forward and the administration of the self-report measures used in Study 2 was combined with the administration of a battery of psychological probes. The aim was not only to see the relationship between hacking expertise and the distribution of the systemizing traits but also the relationship between hacking expertise and the cognitive tasks that were presented in Chapter 3.The target population in Study 2 was the general population.

The choice was motivated by the fact that I wanted to have a good sample size of the database and in Italy I have more contacts than elsewhere.

5 STUDY 2 – Exploring the relationship between hacking tasks and measures of systemizing in the general population

5.1 Introduction

In Study 2, correlations between hacking-like tasks, systemizing and cognitive measures of visuo-spatial ability and field independence were investigated in the general population. Systemizing was investigated with the Systemizing Quotient (SQ; Baron-Cohen et al., 2003), field independence was investigated with the GEFT and the Navon task, of the two visuo-spatial abilities, mental rotation was investigated with the MRT and visual working memory was investigated with the visual working memory task used by Richmond et al., (2013). Moreover, the present study aims to provide new data on the relationship between SQ and the aforementioned behavioural tasks and to fill some gaps in the literature. For example, in the case of mental rotation ability, some authors found a correlation between a short 18-item version of the SQ and the MRT (Ling et al., 2009) while others found no correlation between the two measures (Cook & Saucier, 2010). This study will therefore provide an additional and independent test of the hypothesis of the relation between self-reported systemizing and MRT performance. Two of the tasks used in this study – the GEFT and the visual working memory – have never been assessed together with SQ within the same participants, and the current study will thus fill an existing gap in the literature. Other than the above mentioned measures, the novel scale-r was administered to investigate the relationship between hacking expertise and problem solving abilities. The revised version was the result of the analyses conducted in Study 1. A set of 4 morality items were appended at the end of the novel scale-r to investigate whether hackers and non-hackers differ in their level of morality, and whether the score on the morality traits shows some correlation with the engagement in hacking activities and/or with the hacking expertise. Items were taken from the Levenson's self Report Psychopathy scale (Levenson, Kiehl & Fitzpatrick, 1995), a two factor scale that assesses primary psychopathy and secondary psychopathy traits. Differently from the Psychopathy Checklist-Revised (PCL-R; Hare, Harpur & Hakstian, 1990), that assesses psychopathy traits on imprisoned individuals, the Levenson's scale aimed to assess psychopathy traits in normal, non-institutionalized individuals. Moreover, while the PCL-R is based upon interviews and clinical reports, the Levenson's scale is a self-report assessment and it contains items phrased in a way that "does not signal disapproval of portrait endorsement" (Levenson et al., 1995, p.120). Primary psychopathy consists in a manipulative and selfish attitude, while secondary psychopathy defines an impulsive and self-defeating behaviour. 3 items used in this Study and in Study 3 were taken from the Primary Psychopathy scale and 1 item was taken from the Secondary Psychopathy scale. The reason for this choice is that the focus of interest was more on the manipulative traits as one of the most common hacking activities is social engineering (Mitnik, Simon & Wozniak, 2002), which consists in the psychological manipulation of people to obtain confidential information or to persuade them to do some actions that are necessary for hackers to reach their goals. The item taken from the secondary psychopathy scale was to assess whether hacking expertise might have a relationship with an impulsive behaviour given that literature reports that hackers are thrill-seeking (see Chapter 2), and that impulsive behaviour is correlated with the need for thrill (Magid, MacLean & Colder, 2007). This investigation was an ancillary interest in the study that emerged from discussions on the potential to explore the distinction between ethical and unethical hackers.

The choice to use the original 60-item SQ instead of the revised one (used in the first study) was mainly driven by practicality considerations, i.e. the need to keep the length of the whole questionnaires and battery as short as possible. Although this original version presents a stronger male bias, as it may be more sensitive in detecting systemizing trait in males rather than females, the gender bias was not a major concern for our purposes as in the population of interest – i.e. those with a hacking expertise – males are more represented than females. Nevertheless, additional analyses were performed to control for possible gender-related confounds. To assess problem solving skills and resourcefulness/creativity traits, a modified version of the novel scale used in Study 1 was administered. The revisions were the result of the pilot testing and subsequent data analysis of Study 1. In this revised version items 6 ("I often get stuck and ask other for help"), 8 ("I am afraid of making a mistake and usually this affects the decision I make"), 11 ("I have been told I am a creative person") and 13 ("I feel uncomfortable in taking snap decisions") have been removed. Items 2 and 3 have been transformed into negative sentences to balance the proportion of positive and negative items.

To measure hacking expertise in the general population with no hacking experience or skills three different tasks were developed: a hacking challenge, two crucipuzzles, and a steganography task. Steganography is built on the “concept of hiding information within information” (Parker, 1998, p.48), and the process of hiding is called encryption and it is crucial to information security. We are all familiar with the image of a computer screen full of letters and numbers, in this case the information can be hidden in the meaning of characters or in the pattern they create; or apparently insignificant drawings of everyday scenes, where “secret” messages (usually words) are in fact hidden so well that they require a lot of focused attention to be spotted. These capture the essence of a steganography task, whose rationale represents a mainstay of hacking expertise. One such task was therefore included in the testing battery for Study 2, in which participants were challenged to find a message hidden in a short passage. In crucipuzzles, the search for words embedded in matrices of letters also built on detection skills for meaningful patterns. The hacking challenge was modelled on a task that had been developed in the past for students from the Ethical Hacking degree at Abertay University; for the purpose of this study it was modified and made suitable and available also to non-hackers. The challenge requires inferring transformation rules according to which a hint has to be changed in order to reach subsequent levels. The rationale of this task is the same beyond one of the most common web hacking techniques, the SQL injection. This is a technique based on the insertion of malicious code in a program by substituting snippets of the original code with new malicious ones. It is based on the assumption of inference, because an individual has to infer the syntax of original code, i.e. what the elements stand for, and how to transform them to obtain a successful injection of the malicious code.

Code injection

code:

```
$myvar = "varname";
$x = $_GET['arg'];
eval("\$myvar = \$x;");
```

exploit (injects phpinfo() command which prints very usefull attack info on screen):

```
 example.com/?arg=1
example.com/?arg=1; phpinfo()
```

Note: The example describes a type of ULR injection in which URL code is changed to send malicious info on the screen. It is done by looking at the source code of the web page (CRL+U) and inferring that “arg” is the syntax through which a webpage is launched. By typing into the website URL the command “arg=1” and then “arg=1; phpinfo ()” one can redirect to a different website.

Figure 5.1 Example of an SQL injection.

5.2 Methods

5.2.1 Participants

630 participants completed the first part of the study. Raw data were cleaned as described in the data analysis section and outliers removed. Participants above 60 years old and with learning disabilities were excluded from the analysis. The final sample for the first part was of 573 participants. 151 participants were males (26.4 %) and 422 were females (73.6 %). Age ranged from 17 to 60 years old (mean=37.34, median=35, SD=9.491). As for the academic background, 380 participants were from social sciences[16] (66.3 %), 185 participants were from natural sciences (32.3 %) and 8 were from computing (1.4%). Of those who left their email at the end of the first part, 188 started the second part of the study. Of these, 40 participants completed all the tasks of the second part of the study and 148 completed only some of the tasks, resulting in different sample sizes for each task: 163 for the MRT, 161 for the Raven task, 137 for the visual working memory task, 152 for the GEFT, 134 for the Navon task, 174 for the steganography task (of these, 26 were able to find the correct message), 146 for the crucipuzzles and 130 for the hacking challenge. The study was approved by the Ethics Committee of the School of Social and Health Sciences at Abertay University (see Appendix 2).

5.2.2 Apparatus and Stimuli

The testing protocol for Study 2 included: an Italian version of the SQ, an Italian version of the revised novel scale, an Italian version of the morality scale, a visual working memory test, Raven Matrices short form, MRT, GEFT, a version of the Navon task, and four tasks that targeted hacking-like abilities - two crucipuzzles, a steganography task, and a hacking challenge.

The study was administered entirely online and comprised two parts. The first part involved the administration of a demographic questionnaire, the SQ and a revised version of the novel scale via Google forms. The second part consisted in the

[16] Social sciences included psychology, archaeology, music, law. Natural sciences included biology, physics, chemistry, medicine.

psychological battery and was administered using Inquisit 5 (Millisecond Inc.), a software specifically developed to administer psychological experiments online. Inquisit 5 had to be downloaded locally on participants' laptops or machines just for the duration of the battery, and then it automatically deleted itself after the data was collected. As for this study was necessary to use the mouse, participants were warned not to run it on iPads, tablets or mobile devices[17].

Demographics

The demographic items were designed primarily to check the generalizability of the results, and gather information on participants' experience in hacking. These items relate to respondents' gender, age, highest educational degree achieved, academic background, employment status, job title, involvement in certain hacking activities and self-reported degree of hacking expertise. Specifically the items (which were formulated in Italian) probed the following:

1. "Gender" (options: male, female, other); 2. "What is your year of birth?"; 3. "What is the highest degree or level of schooling you have completed? If currently enrolled, the highest degree received so far" (options: Doctoral or professional degree, Master's degree, Bachelor's degree, Associate's degree, Post-secondary no-degree award, Some college - no degree, High school diploma or equivalent, Less than high school, Other, I prefer not to answer); 4. "What is the subject of your degree?";5. "Are you currently...?" (*referring to employment status (editor's note)* (options, Employed for wages, Self-employed, Out of work and looking for work, Out of work but not currently looking for work, Homemaker, Student, Military, Retired, Unable to work, Other, I prefer not to answer); 6. "In which field do you work? (Skip if unemployed)"; 7. "Do you have any learning disability?"; 8. "If yes, please indicate your learning disability (Options: Dyslexia, Dyscalculia, Dysgraphia); 9. "Are you visually impaired?"; 10. "If yes, are you wearing corrective lenses?"; 11. "In which of the following activities have you ever been involved into? (Select all that apply) (Options: Gained unauthorized access to computer systems, Copied software without authorization, Obtained free telephone/data

[17]Since the device on which the tests were completed is identified and logged in the data file by Inquisit, it was possible to check compliance with this instruction post hoc.

calls by manipulating computer systems, Wrote viruses, Gained unauthorized access to private branch exchanges (PBX) or voice mail systems, Denial of service attacks, Sniffing, Social Engineering, Spoofing, Encryption/Decryption, SQL injection, other, none of the above); 12. “How would you rate your hacking skills?” (On a scale from 1 to 5).

Systemizing Quotient

The SQ (Baron-Cohen et al., 2003) was used in Study 2 – and in Study 3 as described in Chapter 6. The shift from the SQ-R used in Study 1 and the SQ used in Study 2 was motivated by the need to keep the first part as shorter as possible. The 60 item version was preferred to the 75 items because it was time savings and required to keep the attention focused for a shorter amount of time. The male bias that affects the original version used in this study was not of particular concern because on one hand, our population of interests – i.e. those with a hacking expertise – was prevalently male. On the other hand, additional analyses were performed to control for a possible confounding effect by analysing the data according to gender.

It might be argued that the 18 item version developed by Ling et al. (2008) could have been a better choice for the reason of time saving, but it would not have been possible to compare results obtained with the ones present in the literature as the research of interest for the present thesis made use of the SQ and the SQ-r only.

Novel scale - revised

The novel scale-revised comprised nine items that were retained after the factor analysis of Study 1. These nine items were shown to load on to two components: resourcefulness (items 1, 3, 4, 5, 7, 9) and problem solving (items 2, 10, 12). Results from Study 1 demonstrated that these 2 components measured different constructs than the SQ-R. Moreover, hackers scored higher than non-hackers did in both components, but the difference reached the .05 level of significance only for the resourcefulness component. In the scale, “Definitely agree” responses score two points and “Slightly agree“ responses score one point in the following items: 1, 2, 5, 7. “Definitely disagree” responses score two points and “Slightly disagree” responses score one point on the following items: 3, 4, 6, 8, 9 . The total score can theoretically range from 0 to 18. Items of the novel scale-revised are reported in the table 5.1; reverse scored items are with an asterisk, in bold are items that have been rephrased.

Table 5.1 Novel scale-revised

Table 5.1

*Novel scale-revised (reverse scores items are with an asterisks *)*

	Items	strongly agree	slightly agree	slightly disagree	strongly disagree
1	I like trying new things (e.g. hobbies, activities).				
2	**I think it is necessary to find always new and better solutions to a problem, even if the one I have used in the past was successful.**				
3	***I would not define myself as a person who thinks out of the box.**				
4	*I do not like learning new things (e.g. at work and in my spare time).				
5	I believe that no matter what life throws at me, I will be able to handle it.				
6	***When I encounter a problem, I do not usually look at it from different perspectives in order to come up with the best solution.**				
7	I am good at finding solutions to problems that other would not be able to solve.				
8	*I do not feel comfortable with taking new perspectives into things (e.g. change my point of view, find alternatives…).				
9	*When I find a way to solve a situation I do not feel the curiosity to find another way to solve it.				

Morality scale

In Study 2 and Study 3 four items were appended at the end of the novel scale-r to measure morality traits. The aim was to investigate whether low levels of morality might correlate with both levels of hacking skills and the number of hacking activities performed. Moreover, as Study 3 shared the same stimuli and apparatus of Study 2, responses on the four morality items were investigated to check for patterns of individual differences both within the hackers' group and between hackers and non-hackers. As discussed in the Introduction items were taken from the Levenson's scale to assess psychopathy traits (Levenson et al., 1995), and specifically they were: 1) "I enjoy manipulating other people's feelings."; 2) "Even if I were trying very hard to sell something, I wouldn't lie about it."; 3) "In today's world, I feel justified in doing anything I can get away with to succeed."; 4) "Before I do anything, I carefully consider the possible consequences." To maintain consistency with the novel scale-r, the scoring of the four items was a 4-point Likert scale in which "strongly agree" scored 2 point and “slightly agree” scored 1 point on items 1 and 3; while “strongly disagree” scored 2 points and “slightly disagree” scored 1 points on items 2 and 4. The total score ranged from 0 to 8 and represented the degree of amorality, i.e. the higher the score the law the morality levels.

MRT

In the mental rotation task participants are shown pairs of perspective drawings of 3-D shapes and they are required to judge whether the two shapes are identical or if one is a mirror-image of the other one (Shepard & Metzler, 1971).

The procedure used in this study was the same as the one presented by Cook and Saucier (2010).

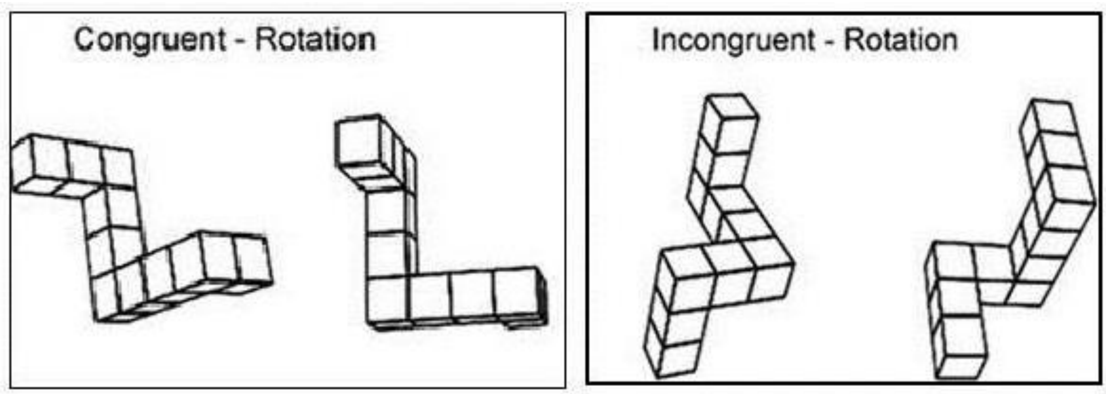


Figure 5.2 Example of congruent (left) and incongruent (right) shapes used in the Mental Rotation test

The set of 24 stimulus pairs (see Figure 5.1) represented two different drawings, each rotated for 45°, 135°, 225° and 315° degrees, and the participants’ task was to decide for each pair whether the two 3-D drawings were of the same shape, or of different shapes, by pressing a button (Q or P) on the keyboard. There were 24 trials without replacement counterbalanced for the two response conditions (same vs. different). After the response was given, participants received a feedback - either “correct” or “wrong” (500ms). The timeout for each trial was 10s, whereas the total time allowed for completing the task was 4 minutes. Participants were instructed to respond as fast as possible while trying to be the most accurate they could in their responses. Variables considered were latency and number of correct responses. Each correct response scored 1 point, so the total score for the task ranged from 0 to 24.

GEFT

An online version of the GEFT (Witkin, 1971) was developed for the purpose of this study and administered via Inquisit. Participants were presented with a simple shape followed by a complex figure in which the simple shape is hidden. Their task was to trace the simple shape embedded in the complex one by mouse clicking the corners of the simple shape. Each mouse click was followed by a feedback: if the response was right then the message “correct” appeared, if the response was wrong the message “wrong” appeared and participants were automatically redirected to the simple shape for 1 second.

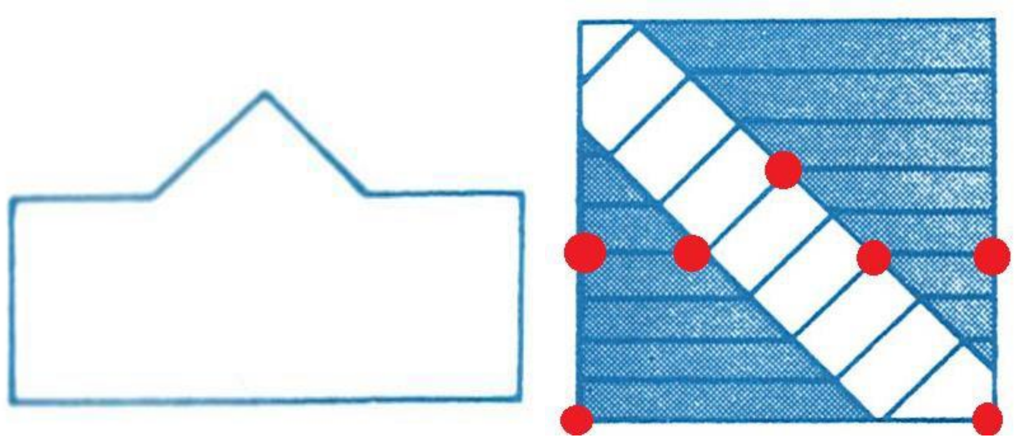
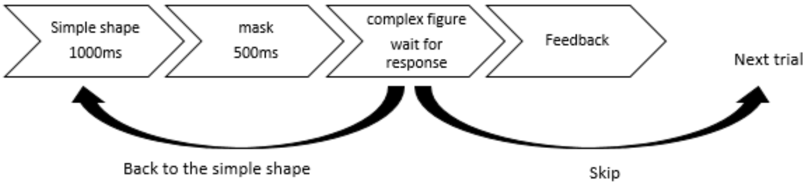


Figure 5.3 Example of a simple figure (left) and a complex figure (right). Highlighted with red dots are the correct mouse clicks.

At the bottom of the screen there were two buttons, the one on the left allowed participants to go back to the simple figure, while the one on the right allowed them to skip the current trial and go on to the next one in case they were stuck.

In total, the test comprised three sections: the first part was a practice phase and it consisted in 7 complex figures, while the second and third parts were the test phases and they both consisted in 9 complex figures in which to detect the simple shape. Time limits were set: for the first part time-limit was 3 minutes while for the second and third parts the time-limit was of 5 minutes each. After each trial participants could read on the screen how much time they had left for the current part. The trial sequence was the following:



The total score was obtained by summing the number of figures correctly traced in the second and third parts, and so the possible scores ranged from 0 to 18. Variables measured were mean latency for each trial and total score.

Visual working memory task

This task comprised two different parts: a recognition task and an order task. In the recognition task participants were asked to judge whether a target shape was presented in a set of 4 shapes they had seen before, while in the order task they were presented with two target shapes and they had to judge which one of the two was presented first in the set of shapes they had seen before. Visual stimuli consist of 30 abstract shapes designed by Vanderplas and Garvin in 1959 for experiments in perception and available at http://www.psych.utah.edu/stat/dynamic_systems/Content/examples/Winter-Conf-04_Paper.html.

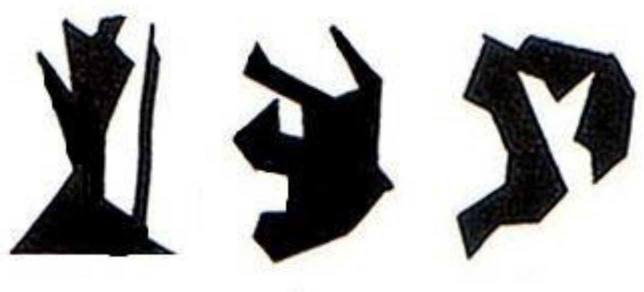
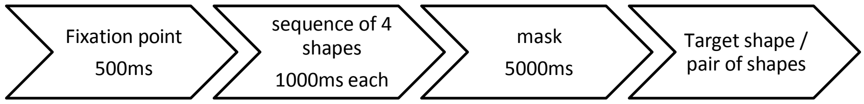


Figure 5.4 Examples of visual stimuli used in the visual working memory task.

These shapes were used because of their abstract nature, preventing the possibility to name them and minimizing the contribution of verbal working memory to the task (Richmond et al., 2013). The list of four shapes was used according to the demonstrated capacity limit of four items for visual information (Luck & Vogel, 1997).

As mentioned before the experimental set up replicated the one used by Richmond et al. (2013). Each part consisted of 45 trials in which the list of four shapes presented and the target shape were randomly selected from the total sample of shapes, for a total of 90 trials. The first two trials of each condition (recognition and order) were for practice.

The experimental sequence was the following.



The total score (number of correct responses) can thus range from 0 to 90. Number of correct responses and reaction time were logged for every trial in the recognition and the order tasks.

Raven Matrices

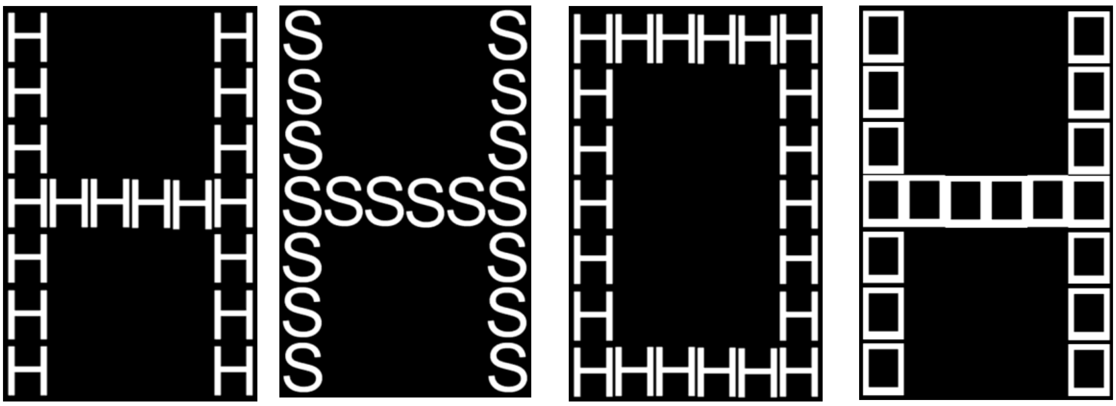
The short version of the Raven's Standard Progressive Matrices (RSPM) was used to assess mental ability associated with abstract reasoning - i.e. fluid intelligence (Cattell, 1963). It's a multiple-choice test in which participants are presented with 9 figures with a missing piece. Below each figure different possible matches are shown and participants' task is to decide which one is the correct correspondence with the missing piece. The pattern matching is of increasingly difficulty. Each correct recognition scores 1 so the minimum total score is 0 and the maximum total score is 9. No time limit was set for this task.

This abbreviated version was developed and validated by Bilker, Hansen, Brensinger, Richard, Gur & Gur (2012), and it was demonstrated that it predicts the total score for the 60-items scale with good accuracy. There are two versions – Form A and Form B, and they can be used instead of the original 60 items scale saving a considerable amount of time. The items included in Form A are: 11, 24, 28, 36, 43, 48, 49, 53, and 55 from the original 60-item Raven's scale. The items included in Form B are: 10, 16, 21, 30, 34, 44, 50, 52, and 57 from the original 60-items Raven's scale. Form A has correlations of r=.9836 and Form B has correlations of r=.9782 to the long form. Even though there are reduced number of items to represent the six general categories of abstract reasoning, content validity is supported by an average correlation of r=.71 across reasoning domains.

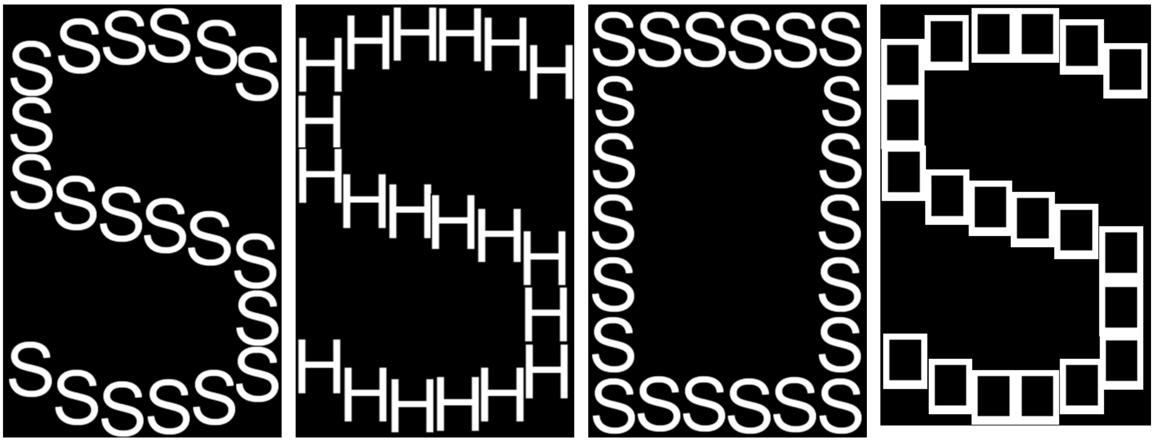
The abbreviated version was used in the current study for time-saving reasons, as the battery as a whole comprised several tasks. . Number of correct responses and mean latencies were logged.

Global/Local task

The classical Navon paradigm was used (Navon, 1977). Participants were briefly presented with letter shapes (e.g. H or S) made up of small letter shapes (e.g. H or S). Some of these letters had the same global (overall shape) and local (individual building shapes) letters (e.g. a global H that is made with local Hs), and some have different global and local letters (e.g. a global H that is made with local Ss). In the global condition participants were asked to respond to the global shape of the letter (e.g. press key H if the global shape of the letter is an H regardless of individual building blocks); in the local condition participants were asked to respond to the local shapes of the letter (e.g. press H if the local building elements are Hs regardless of overall shape). There were therefore two conditions (global vs. local) tested within, their order being counterbalanced by group number; and three levels of congruency (congruent vs. neutral vs. incongruent; see fig. 5.4).



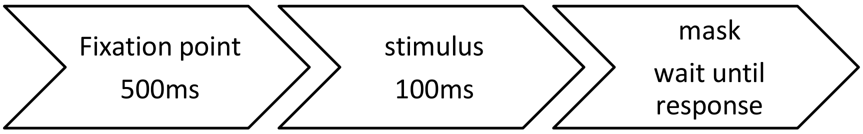
Congruent **Incongruent** **Neutral in the global condition** **Neutral in the local condition**



Congruent | **Incongruent** | **Neutral in the global condition** | **Neutral in the local condition**

Figure 5.5 Examples of stimuli and conditions used in the Navon task with letter H (above) and letter S (below). From left to right: congruent, incongruent, neutral in the global condition and neutral in the local condition.

Altogether, there were eight blocks of 24 trials, the first two blocks of each condition were for practice and the remaining six were the testing phases. In total there were 192 trials. The 6 stimuli per condition (letter H made of Hs, letter S made of Ss, letter H made of Ss, letter S made of Hs, letter H made of rectangles or vice versa, letter S made of rectangles or vice versa) were presented 4 times with a random selection. Stimuli could be presented randomly either in any of the four screen quadrants or in the centre of the screen. Each trial had the following sequence:



The inter trial interval was of 3 seconds. Latencies were measured from the onset of a stimulus till the participant's response. Maximum score was 72 for each condition (global or local), and 144 for the entire task. Different scores were created from the reaction times of correct responses in the Navon task:

- Global bias: mean RT in the incongruent local condition – mean RT in the congruent local condition.

- Local bias: mean RT in the incongruent global condition – mean RT in the congruent global condition.
- Local/global precedence: mean RT in the local condition – mean RT in the global condition.

Accuracies for every congruency level in both conditions were also calculated.

Hacking challenge

This task consisted in a sequence of problems of increasing level of difficulty. Participants were presented with a hint on the screen and they had to find out how to reach the next level by typing the correct response. There were 21 levels in total. An example might clarify: if the hint presented was “1” the correct response in order to reach the following level was “2”, if the hint was “EVIF” the correct response was “XIS”, if the hint was “VIII” the correct response was “IX” and so on. There were different rules according to which the hint was related with the correct answers: names of planets, roman numerals, numbers written in a different language, alternating upper and lower case letters etc. Thus this task, which is also used for training purposes in the Ethical Hacking degree course, heavily rests on individual knowledge of ordered series of information, deductive reasoning and contingent pattern detection. The time-limit for the entire task was 5 minutes and variables collected were accuracy and response time. The minimum score was 0 and maximum score was 21. Number of correct responses and mean latencies were logged.

Steganography task

In this task a secret message was embedded in a piece of text and the participants were required to find the hidden message consisting in 4 words. They were asked to type the words in the space provided and received a positive or negative feedback after every input. To exemplify the task, the message presented to the English sample in Study 3 is reported here below. The message used in Study 2 was an Italian version with the same rationale. In both cases, the hidden message had to be found by connecting the first letters of each word in the second sentence. In the example shown here, the message was: “DO NOT TRUST COLIN”. Correct recognitions of the hidden message – i.e. message found or message not found - and mean latencies were logged.

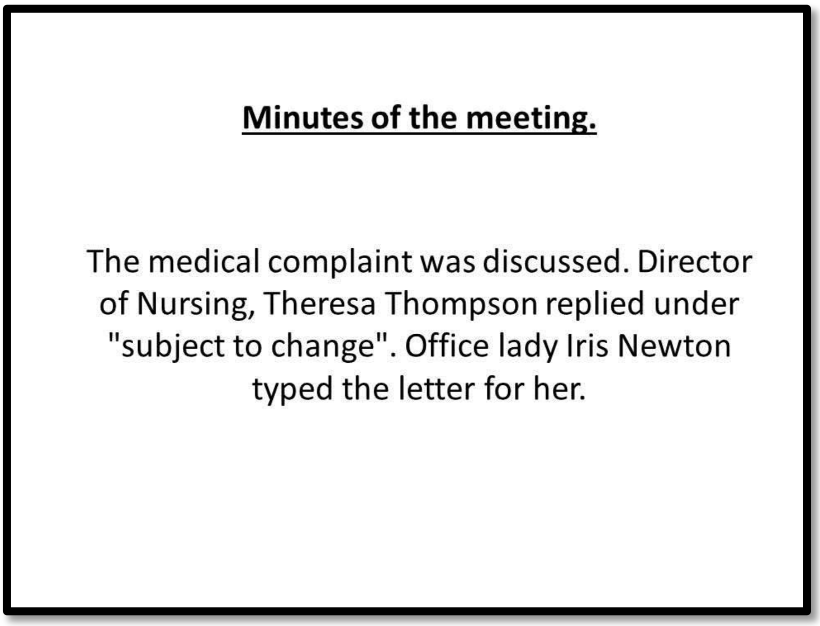


Figure 5.6 Stimulus used for the steganography task.

Crucipuzzles

In the two crucipuzzles participants were required to find 6 meaningful words in a matrix of letters among 29 possible words that can be found in the matrix (see figure 5.7). The matrix was presented at the centre of the screen and participants had to type one word at a time, then press enter. The response was followed by a positive or negative feedback. The maximum available time for the task was 5 minutes. The maximum score achievable for this task was 6. Number of correct words found and mean latencies for each word found were logged.

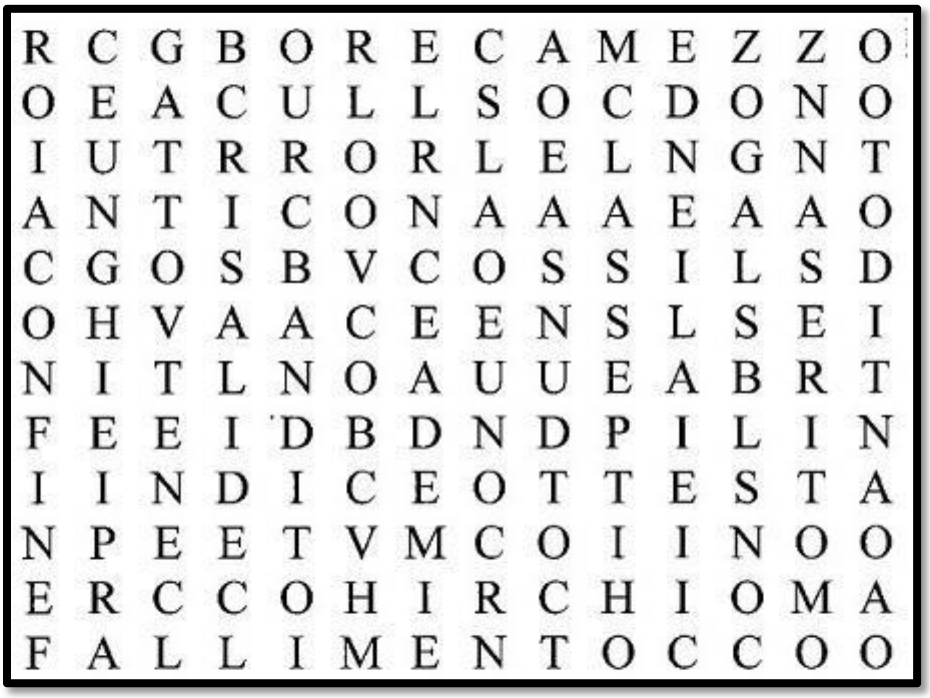


Figure 5.7 Example of stimuli used in the crucipuzzles task.

5.1.1 Procedure

Participants were recruited by an advertisement posted on social networks, sent through mailing lists and university newsletters. The advertisement described briefly the study, declared who the researcher was and at which university the project was based and provided at the end a link to the first part of the study. By clicking the link participants were redirected to a Google form with a series of questionnaires. Before beginning, an informed consent form was to be read and approved; at the end of the questionnaires, participants were properly debriefed and asked whether they agreed to volunteer also for the second part of the project. At this point, three options were given to them: (a) to participate to the second part and consent to the use of their data; (b) to not participate to the second part and withdraw consent to the use of their data for the first part; (c) to not participate to the second part while consenting to the use of their data for the first part. Participants who decided to volunteer also for the second part were asked to type their email in the space provided, so that they could receive a link to the battery of tasks with an individual ID number assigned by the researcher. Contact data were kept in a password-protected file and separated from the numerical ID list. Numerical IDs were used to link the anonymised responses provided by a participant in the first part of the study and his/her performance data in the second part of the study. The second part was administered online on Inquisit web platform (Millisecond Inc.); it consisted in a sequence of nine different tasks that demanded participants' undivided attention for approximately 45 minutes. The order in which the tasks were presented was randomized to avoid systematic order effects across the entire sample. When participants browsed to the experiment launch page and clicked "Start", they were asked to download the Inquisit 4 engine locally to their machine. The engine size was about 4 MB, so it took just a few seconds to download, and it was wrapped in several different web technologies for compatibility with a wide variety of browsers and platforms. Before starting the second part, an informed consent form was presented to the participants who could then still choose to freely consent to participate or not to participate. In this latter case, the experiment would abort straight ahead. If they consented, then a screen briefly summarized what they were asked to do. Detailed information regarding each task was given at the beginning of the task itself. Before starting the battery participants were told that the use of the mouse was necessary for the experiment and that the tests would have required their focused attention for about 45 minutes, so they were kindly asked to switch off their mobiles/tablets and avoid any distraction during the time of the experiment.

5.3 Data analysis

The study was a correlational study between subjects. Demographic data, either nominal (i.e. gender, subject degree), ordinal (i.e. self-rating of hacking skills) or ratio (i.e. age) was used as independent variables. Questionnaire item scores were treated as ordinal variables (Field, 2009), whereas their total scores were regarded as ratio data. Items scores and total scores were treated as dependent variables. For the psychological tasks and the hacking-like tasks used in the battery, number of correct responses and reaction times (when available) for correct responses were measured and treated as dependent variables. In order to keep extraneous systematic variation to a minimum, randomization and counterbalancing were used. Randomization was ensured by randomly deciding the sequence in which the tasks were presented to a given participant; and on the other hand conditions within each task were counterbalanced when possible. Guidelines for sample size suitability in a multiple correlation analysis given by Cohen (1992) are limited to 8 variables, and in the present study there are far more than 8 variables, as we have 20 variables in total. However, his recommendation in the case of 8 variables is 147 participants to detect a medium effect size (f^2=.15) at power =.80 for α=.01; an increase of 10 participants for each variable added was hypothesised based on the pattern given in the table provided by Cohen (1992) the minimum number of participants was set to 270. An initial cleaning of the raw data was performed to remove participants who did not complete a task in its entirety. Data from test phases were separated from data from instruction, rest and feedback phases, and only the former were included in the analysis. Correct responses were separated from errors. Accuracies and reaction times were used as dependent variables. Extreme outliers were identified and removed according to the outlier labelling rule (Hoaglin et al., 1986).

Descriptive statistics were first calculated for all the variables. Not all the variables met all parametric test assumptions so non-parametric tests were used. Non-parametric bivariate correlations were obtained for all the variables. Mean differences with different grouping variables were investigated with Mann-Whitney and Kruskal-Wallis tests, using the appropriate Bonferroni-Holm[18] corrections for multiple comparisons. Principal Component Analyses (PCA) were performed on the SQ to compare the results with those reported in the literature and to investigate whether some components could be extracted that might have stronger correlations with hacking expertise. PCA was conducted also on the novel scale-r both to compare component structure with the one obtained in Study 1 and to investigate individual differences and correlations between components and hacking expertise.

5.4 Results

5.4.1 Descriptive statistics

412 participant had never performed any hacking activity, the others reported the following numbers of hacking activities: 112 participants reported 1 hack, 20 participants reported 2 hacks, 6 participants reported 3 hacks, 5 participants reported 4 hacks, 5 participants reported 5 hacks, 3 participants reported 6 hacks, 1 participant

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18 [illegible]+1

reported 8 hacks, 8 participants reported 9 hacks and only one participant reported 10 hacks. Males reported more hacks (mean=1.07, SD=1.68, median=1, IQR=1) than females (mean=.38, SD=1.29, median=0, IQR=0). Comparing groups according to the academic background on the number of hacking activities, participants with a computer science background reported a higher number of hacking activities (mean=4.88, SD=2.9, median=5, IQR=5) than those with a science background (mean=.74, SD=1.34, median=0, IQR=1) and those with a social science background (mean=.38, SD=1.27, median=0, IQR=0). As regards the self-report rating of hacking skills on a scale from 0 to 5, 431 participants reported 0, 83 reported 1, 35 reported 2, 17 reported 3, 3 reported 4 and 4 reported 5. Males reported having higher level of hacking skills (mean=.81, SD=1.06, median=.00, IQR=1) than females (mean=.27, SD=.73, median=0, IQR=0). Participants with a computer science background reported higher levels of hacking skills (mean=2.13, SD=1.46, median=2, IQR=2) than participants with a science background (mean=.59, SD=.88, median=0, IQR=1) and participants with a social science background (mean=.29, SD=.78, median=0, IQR=0).

SQ scores ranged from 5 to 61 (mean=31.83, median=31, SD =9.64), novel Scale-r scores ranged from 1 to 18 (mean=10.15 median=10, SD=3.48) and morality scale scores ranged from 0 to 5 (mean=0.69, median=0, SD=1.03)

As the steganography task did not have a range of scores, because a participants could only either find the message or not, descriptive statistics for this task are reported only for the reaction times for correct responses. 30% of participants got the correct answer (N=172) .

On the overall sample, the Navon local interference effect was found. Mean RT in the local condition for the total sample was slower (mean=758.72, SD=165.46) than in the global condition (mean=600.18, SD=198.37). On RTs, the global bias was bigger (mean=61.91, SD=169.85) than the local bias (mean=5.38, SD=63.51) indicating that overall participants experienced the effect of local level distractors. The mean accuracies in the global condition was higher (mean=95.67, SD=6.14) than the mean accuracies in the local condition (mean=59.14, SD=13.86).

Statistics for SQ, novel scale-r, morality scale and the behavioural tasks according to gender are reported below. Descriptive statistics for all tasks according to academic background are also reported. For computer science students, descriptive statistics are not provided because of too few cases, i.e. 4 participants completed the

MRT, the Raven task and the visual working memory, 3 participants completed the GEFT, the crucipuzzles and the hacking challenge, 2 participants completed the Navon task and only one participant completed the steganography task.

Table 5.2 Descriptive statistics for all tasks according to gender.

Table 5.2

Descriptive statistics for all tasks according to gender (number of participants is given in the first row of each task).

	Males				**Females**			
	Mean (s.e.)	**Median**	**St.Dev**	**IQR**	**Mean (s.e.)**	**Median**	**St.Dev**	**IQR**
SQ	36.95 (.75)	36.00	9.27	13.00	29.98 (.44)	30.00	9.12	12.00
N	151				422			
Novel scale-r	10.15 (.29)	10.00	3.57	6.00	10.15 (.16)	10.00	3.45	5.00
N	151				422			
Morality scale	.91 (.09)	.00	1.13	2.00	.62 (.05)	.00	.98	1.00
N	151				422			
MRT score	17.24 (.63)	17.00	4.44	7.00	15.51 (.34)	15.00	3.70	6.00
N	49				114			
MRT RT	3278.76 (176.87)	3407.43	1238.09	2000.8	3452.35 (118.65)	3671.99	1266.86	1817.1
Raven score	6.04 (.23)	6.00	1.58	2.00	5.81 (.16)	6.00	1.74	2.00
N	47				114			
Raven RT	17330.35 (996.83)	16760.00	6833.96	8099.0	17370.67 (684.67)	16134.08	7310.28	9805.55
GEFT score	17.22 (.20)	18.00	.13	1.0	16 (.26)	17.00	2.79	3.0
N	44				108			
GEFT RT	15164.35 (443.42)	15275.24	2941.33	3984.38	15296.77 (325.14)	15695.36	3379.00	4946.43
Recognition score	12.22 (.31)	12.00	1.95	2.00	11.44 (.20)	11.00	1.98	3.00
N	40				97			
Recognition RT	1578.09 (59.95)	1512.35	379.18	550.44	1538.20 (40.17)	1460.92	395.60	462.01
Order score	16.65 (.59)	17.00	3.74	6.00	17.01 (.28)	17.00	2.80	4.00
N	40				97			
Order RT	1944.23 (98.69)	1793.62	624.21	756.75	2005.41 67.29	1937.00	662.73	662.72
Navon local mean RT	761.83 24.73	733.75	146.28	204.75	757.61 (17.35)	750.98	172.40	212.02
N	35				99			
Navon global mean RT	556.89 (14.91)	554.41	88.21	99.35	615.48 (22.42)	565.55	223.16	130.34
Global bias	65.24 (29.33)	67.45	155.22	159.59	60.75 (19.63)	51.61	175.61	204.98
Local bias	9.66 (12.72)	-2.18	69.68	50.04	3.85 (6.71)	-4.55	61.53	55.12
Local/global Precedence	204.94 (26.16)	190.34	154.76	218.54	142.13 (23.83)	139.92	237.16	214.56

Crucipuzzle score	10.1 (.20)	10.00	1.31	2.00	10.14 (.13)	10.00	1.38	2.00
N	40				106			
Crucipuzzle RT	20070.60 (946.62)	19473.10	5986.99	7776.08	18937.61 (519.50)	18591.3	5348.66	8773.18
Hacking challenge score	2.14 (.08)	2.00	.49	.00	2.17 (.06)	2.00	.58	.00
N	35				95			
Hacking challenge RT	5608.42 (607.45)	4176.00	3593.74	3687.0	6786.20 (359.12)	5910.00	3500.31	4778.00
Steganography RT	22173.02 (4354.45)	17483.75	13063.3	19182.6	22213.14 (3271.23)	17087.0	13487.63	21897.2
N	9				17			

Table 5.3 Descriptive statistics for participants with a science background

Table 5.3

Descriptive statistics for participants with a science background (number of participants is given in the first row of each task).

	Science background			
	Mean (s.e.)	**Median**	**St.Dev**	**IQR**
SQ	34.83 (.73)	33.00	9.93	15
N	185			
Novel scale-r	10.24 (.26)	10.00	3.49	5.50
N	185			
Morality scale	.87 (.08)	.00	1.12	2.00
N	185			
MRT score	16.52 (.47)	17.00	3.93	7.00
N	69			
MRT RT	3471.34 (151.81)	3767.60	1261.07	1890.40
Raven score	6.10 (.19)	6.00	1.57	2.00
N	68			
Raven RT	16824.29 (852.37)	16335.37	7028.85	8790.84
GEFT score	16.48 (.28)	18.00	2.34	3.00
N	68			
GEFT RT	14923.21 (368.1)	15192.92	3035.45	3877.57
Recognition score	11.75 (.27)	12.00	2.09	3.00
N	61			
Recognition RT	1630.08 (49.67)	1577.00	387.97	538.92
Order score	17.11 (.41)	18.00	3.17	3.00
N				
Order RT	2053.72 (81.9)	2019.39	639.71	869.71
Navon local mean RT	742.59 (20.96)	735.56	155.47	215.32
N	55			
Navon global mean RT	573.47 (15.91)	548.75	117.99	107.00
Global bias	80.86 (23.20)	95.83	157.36	147.72
Local bias	1.93 (7.26)	-8.67	50.32	52.99
Local/global precedence	169.12 (20.22)	157.35	149.95	218.65
Crucipuzzle score	10.00 (.17)	10.00	1.39	2.00
N	61			
Crucipuzzle RT	18139.24 (624.58)	17862.63	4878.13	5906.05
Hacking challenge score	2.06 (.07)	2.00	.57	.00
N	53			
Hacking challenge RT				
Steganography RT	17172.74 (3198.1)	15062.25	10112.99	14587.75
N	10			

Table 5.4 Descriptive statistics for participants with a social science background

Table 5.4

Descriptive statistics for participants with a social science background (number of participants is given in the first row of each task).

	Social science background			
	Mean (s.e.)	**Median**	**St.Dev**	**IQR**
SQ	30.24 (.47)	30.00	9.16	13
N	380			
Novel scale-r	10.11 (.18)	10.00	3.49	5.00
N	380			
Moral scale	.59 (.05)	.00	.97	1.00
N	380			
MRT score	15.65 (.42)	15.50	4.00	6.00
N	90			
MRT RT	3362.48 (133.24)	3384.24	1264.01	1937.42
Raven score	5.69 (.19)	6.00	1.79	3.00
N	89			
Raven RT	17721.33 (785.26)	16656.50	7408.13	10138.77
GEFT score	16.22 (.30)	18.00	2.71	3.00
N	81			
GEFT RT	15613.06 (377.62)	16183.00	3398.56	4690.43
Recognition score	11.62 (.23)	11.50	1.95	3.00
N	72			
Recognition RT	1480.21 (45.70)	1409.15	387.82	440.00
Order score	16.89 (.34)	17.00	2.88	4.00
N				
Order RT	1922.42 (76.34)	1840.34	647.75	904.69
Navon local mean RT	773.68 (19.68)	758.73	172.72	229.84
N	77			
Navon global mean RT	621.26 (27.36)	572.51	240.13	114.19
Global bias	49.54 (23.29)	43.23	181.16	212.61
Local bias	8.48 (9.11)	1.55	72.91	56.86
Local/global precedence	152.42 (29.73)	145.89	260.89	240.44
Crucipuzzle score	10.26 (.15)	10.00	1.35	2.00
N	82			
Crucipuzzle RT	19864.98 (613.19)	19597.41	5552.75	9788.71
Hacking challenge score	2.24 (.06)	2.00	.54	1.00
N	74			
Hacking challenge RT	7229.29 (412.78)	6315.75	3550.91	4711.12
Steganography RT	23725.68 (3322.91)	17671.75	12869.60	19074.50
N	15			

5.4.2 Parametric assumption check

Parametric assumptions were first checked for the self-report measures and the cognitive measures according to gender. For SQ and the novel scale –r mean and median were similar and the standard deviations were smaller than the mean in both groups. For the morality scale, mean and median were not similar, as the median in both males and females was 0, and the standard deviations were bigger than the means.

A first look at the values of skewness suggested a deviation from a normal distribution for both males (.357, s.e. =.197) and females (.246, s.e.=.119) in the SQ, while in the novel scale-r the distribution was quite normal for males (.022, s.e.=.197) but not for females (-.132, s.e.=.119). Values of kurtosis suggested a platykurtic distribution for males in both the SQ (-.547, s.e.=.392) and the novel scale-r (-.705, s.e.=.392) and for females in the novel scale-r (.-.588, s.e.=.237) but not in the SQ (-.033, s.e.=.237). In the morality scale skeweness for males was 1.21 (s.e.=.197) and for females was 1.88 (s.e.=.119); kurtosis for males was 1.09 (s.e.=.394) and for females was 3.78 (s.e.=.237); indicating a positively skewed and leptokurtic distribution for both males and females. To have more information, Z scores of skewness were calculated for the SQ (males=1.81; females=2.07) the novel scale-r (males= .11; females = -1.11) and the morality scale (males=6.16; females=15.79). Z scores for kurtosis were also calculated for SQ (males= -1.39; females=-.14), the novel scale-r (males=-1.80; females=-2.48) and the morality scale (males=2.8; females=15.91).
All values except for the skeweness in the novel scale and the kurtosis in the SQ were above the significant value of 1.95, $p < .05$. Tests of Normality confirmed that the distribution was different from normal in all measures (see appendix D, table D1).

Because in large samples normality tests can be significant also when the scores are only slightly different from a normal distribution (Field, 2009), I looked at histograms and Q-Q plots (see appendix D, figures D1-D3), which confirmed that the distributions deviated from normality. Homogeneity of variances was confirmed by the Levene test's output for SQ (.850 (1,571), p=.357), the novel scale-r (.829 (1,571), p=.363) but not for the morality scale (5.336 (1,571), p=.021). Data was considered to be not normally distributed so non-parametric tests were used for the analyses involving self-report data. Parametric assumptions were also checked for all the psychological tasks. For some tasks - MRT RT, GEFT score, order RT , MRT score, Raven RT, and recognition RT for females– mean and median were not similar. Standard deviations were smaller than the mean in all tasks for both conditions. Values of skeweness and kurtosis showed a deviation from a normal distribution in almost all task. Levene's test was significant for order score, and GEFT score indicating non-homogeneity of variances for these tasks. Test of Normality confirmed a deviation from a normal distribution, as only for GEFT RT and all four p-values were above .05. For these reasons, non-parametric tests were chosen for correlations (Spearman's rho), bivariate correlation (Kendall's T xy,z) and mean comparisons (Mann-Whitney and Kruskal-Wallis tests).

5.4.3 Principal Component analyses

5.4.3.1 PCA of the SQ

The PCA aimed at investigating whether some components could be extracted that might show a relationship with hacking expertise. In Study 1 it was found that hackers scored higher than non-hackers on the SQ-R, here it is tested whether some components of the SQ might add more value to the instrument as a whole in discriminating between those with hacking expertise and those without it. As explained in section 3.4.1 the four factor model of the SQ provided by Ling et al. (2009) had the best fit statistics as compared to other models discussed in literature.

To check whether the structure provided by Ling et al. (2009) applied also to these results, a PCA with promax rotation was conducted with the 18 items extracted by the author imposing the extraction of 4 components. Overall the cumulative variance explained was 44%, slightly less than the one explained in the analysis reported above. Four components were extracted with Eigenvalue above 1. Component 1 explained 20% of the variance, Component 2 explained 9.5%, Component 3 explained 7.6% and Component 4 explained 6.7%

The loadings were different from those found by Ling et al. (2009) reported in table 5.7.

Table 5.5 Pattern Matrix of the shortened 18 items version of the SQ

Table 5.5

Pattern Matrix of the shortened 18 items version of the SQ

Item	**Component**			
	1	**2**	**3**	**4**
SQ20	.825			
SQ33	.768			
SQ5	.732			
SQ11				
SQ31		.830		
SQ24		.788		
SQ49		.698		
SQ18		.399		
SQ40		.338		

SQ37			.781	
SQ48			.737	
SQ26			.585	
SQ7			.334	
SQ51				
SQ15				
SQ35				.683
SQ45				.613
SQ43				.527

Table 5.6 Structure Matrix of the shortened 18 items version of the SQ

Table 5.6

Structure Matrix of the shortened 18 items version of the SQ

	Component			
	1	**2**	**3**	**4**
SQ20	.820			
SQ33	.787			
SQ5	.691			
SQ11	.392			
SQ31		.796		
SQ24		.765		
SQ49		.717		
SQ18		.464		
SQ40		.382		
SQ37			.799	
SQ48			.718	
SQ26			.587	
SQ7			.410	
SQ51			-.343	
SQ15			.307	
SQ35				.696
SQ45				.591
SQ43				.584

Some items aggregated together in the same way as Ling et al. (2009) found, while some others showed a different loading. Two items – 40 ("I find it difficult to understand information the bank sends me on different investment and saving systems") and 43 ("If I were buying a camera, I would not look carefully into the quality of the lens") that on Ling et al. (2009) loaded on the Technicity factor, in the present study loaded differently. Item 40 loaded to the Ling et al.'s (2009) Topography factor; while item 43 loaded to a different component with items 35 and 45 as explained in the following lines. An additional item of the Ling et al.'s (2009) Topography factor was item 18 ("I find it difficult to understand instruction manuals for putting appliances together"). In the present study, the Ling et al.'s (2009) DIY factor was not found; in fact, the most representative item of this factor - item 35 ("I am not very meticulous when I carry out D.I.Y") – loaded with item 43 and item 45 ("When I hear the weather forecast, I am not very interested in the meteorological patterns") in the same component. Item 7 ("If there was a problem with the electrical wiring in my home, I'd be able to fix it myself") loaded to the Ling et al.'s (2009) Structure factor, while in their study it loaded on to the DIY factor.

Table 5.7 Comparison between factors' structure of the shortened 18 items version of the SQ (Ling et al., 2009) and components' structured obtained in the present study.

Table 5.7

Comparison between factors' structure of the shortened 18 items version of the SQ (Ling et al., 2009) and components' structured obtained in the present study

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Component	Author(s)	Items
Technicity	Ling et al. (2009)	5, 11, 20, 33, 40, 43
Component 1	Study 2	5, 11, 20, 33
Topography	Ling et al. (2009)	24, 31, 49
Component 2	Study 2	**18**, 24, 31**, 40**, 49
Structure	Ling et al. (2009)	15, 26, 37, 45, 48, 51
Component 3	Study 2	**7**, 15, 26, 37, 48, 51
DIY	Ling et al. (2009)	7, 18, 35
Component 4	Study 2	35, **45, 43**

As the loading of items on components is quite similar to the one obtained by Ling et al. (2009), the four components were investigated in relations with measures of hacking expertise to test whether they might be more discriminative than the total SQ between those with hacking expertise and those without it.

5.4.3.2 PCA of the novel scale-r

A PCA with promax rotation was conducted on the novel scale-r to validate results from Study 1. Two components were extracted with Eigenvalues above 1 and together explained 42% of the variance, component 1 explained 30% and component 2 explained 12%. The two components correlated well together (r=.404) and the consistency of the scale was good (Cronbach's alpha=.709).

Table 5.8 Pattern matrix of the novel scale-r

Table 5.8
Pattern matrix of the novel scale-r

	Component	
Item	**1**	**2**
8	.717	
9	.689	
4	.634	
6	.606	
3	.342	

5	.800
7	.737
2	.584
1	.412

Table 5.9 Structure Matrix of the novel scale-r

Table 5.9
Structure matrix of the novel scale-r

	Component	
Item	**1**	**2**
8	.743	
9	.664	
6	.618	
4	.594	
3	.457	
7		.733
5		.720
2		.624
1		.510

The distribution of the items was different from the one that emerged in Study 1. The items that loaded differently are reported in bod in the table below. Given the over representation of females in this study (N=422) over males (N=151) other PCAs were conducted with only male sample, with only female sample; and with random sampling. The distribution of the items on to the two components was not consistent in all analyses conducted.

Table 5.10 Components' structure of the novel scale-r.

Table 5.10
Components' structure of the novel scale-r

COMPONENTS	Loadings
1	
8. *I do not feel comfortable with taking new perspectives into things (e.g. change my point of view, find alternatives…).	.717
9. *When I find a way to solve a situation I do not feel the curiosity to find another way to solve it.	.689
4. *I do not like learning new things (e.g. at work and in my spare time).	.634
6. *When I encounter a problem, I do not usually look at it from different perspectives in order to come up with the best solution.	.606
3. *I would not define myself as a person who thinks out of the box.	.342
2	
5. I believe that no matter what life throws at me, I will be able to handle it.	.800
7. I am good at finding solutions to problems that other would not be able to solve.	.737
2. I think it is necessary to find always new and better solutions to a problem, even if the one I have used in the past was successful.	.584
1. I like trying new things (e.g. hobbies, activities).	.412

Differences cannot be accounted for by the shared variance of items 1, 2, 3, 8; as also items 4, 5, 5, 7, 9 loaded differently on all the analyses without any consistent pattern. So it might be that the scale can be better considered as one component scale assessing problem solving abilities and resourcefulness/curiosity. A Maximum Likelihood analysis was conducted to compare the two components model and the model with one component. The Goodness of fit was better for the model with one component χ^2 (27) = 209.303, p=.000 rather than the model with two components χ^2 (19) = 114.528, p=.000. The variance explained by the one component model was almost 22%, and the addition of a second component increased the variance only to 27%.

5.4.3.3 Combined PCA of all items of the SQ and the novel scale-r

After having conducted the principal component analyses on the SQ and on the novel scale-r alone; I thought it was useful to conduct another analysis on the two measures taken together to obtain more information on the patter of aggregation of the items. A combined PCA was conducted with all items of the SQ and the Novel scale-r to investigate the pattern of aggregation of the items. All items of the novel scale-r aggregated together in components independently from the items of the SQ (see Appendix D, table D2). The items aggregation was slightly diifferent from the one obtained analysing only the novel scale-r alone. In this latter analysis two components were extracted (see section 5.4.3.2): component 1 comprised items 8,9,4,6,3; component 2 comprised items 5,7,2,1. As reported in the Appendix D, when the analysis was conducted with all items of the two self-report measures together, items of the novel scale-r showed a different pattern of aggregation. Items 9,8,6,3 loaded on to component 5 with item 23 of the SQ ("When I cook, I do not think about exactly how different methods and ingredients contribute to the final product"), while item 4 loaded on to component 15 with items 1 ("When I listen to piece of music, I always notice the way it's structured") and item 7 ("If there was a problem with the electrical wiring in my home, I'd be able to fix it myself"). Differently from the analysis on the novel scale-r alone, items 1 and 2 loaded on to component 7 while items 5 and 7 formed ccomponent 8. This analysis, even if showed a different aggregation of the items of the novel scale, gave evidence to the independence of the novel scale from the SQ-R, supporting the idea that the novel scale measured different components from the SQ-R.

5.4.3.4 Combined PCAs of the SQ, the novel scale-r, and the morality scale

A combined analysis of the novel scale –r and the SQ was conducted to investigate whether the two questionnaires measured different components.

The two components structure of the novel scale-r remained the same, with the SQ score loading on to the first component. The correlation between the two components was r=.422.

Table 5.11 Pattern matrix of the novel scale-r and SQ total score

Table 5.11
Pattern matrix of the novel scale-r and SQ total score

	Component	
Item	**1**	**2**
9	.705	
8	.704	
4	.632	
6	.587	
SQ	.359	
3	.348	
5		.498
7		.439
2		.582
1		.404

Table 5.12 Structure matrix of the novel scale-r and SQ total score

Table 5.12
Structure matrix of the novel scale-r and SQ total score

	Component	
Item	**1**	**2**
8	.722	
9	.675	
6	.591	
4	.585	
SQ	.472	
3	.465	
7		.734
5		.704
2		.625
1		.502

To check the independence of the three questionnaires, a PCA was conducted on the total scores of the three measures. The analysis suggested the presence of three components and the scree plot confirmed the presence of three distinct points. The first component accounted for the 46% of the variance, the second component explained 34% and the third component explained 21% of the variance. Altogether the three components explained 100% of the variance.

Figure 5.8 Scree-plot of the three components

SQ and novel scale-r were correlated (r=.368), but the morality scale was not correlated with the SQ (r=-.049) nor with the novel scale-r (r=.051).

5.4.4 Score comparisons between groups

An effect of gender was found on SQ scores where males scored higher (mean=36.95, SD= 9.27) than females (mean= 30.00, SD= 9.17), U=19207, z=-7.252, p=.000, r= .30, medium effect. No effect of gender was found on the novel scale-r, U=31610.5, z=-.144, p=.886.

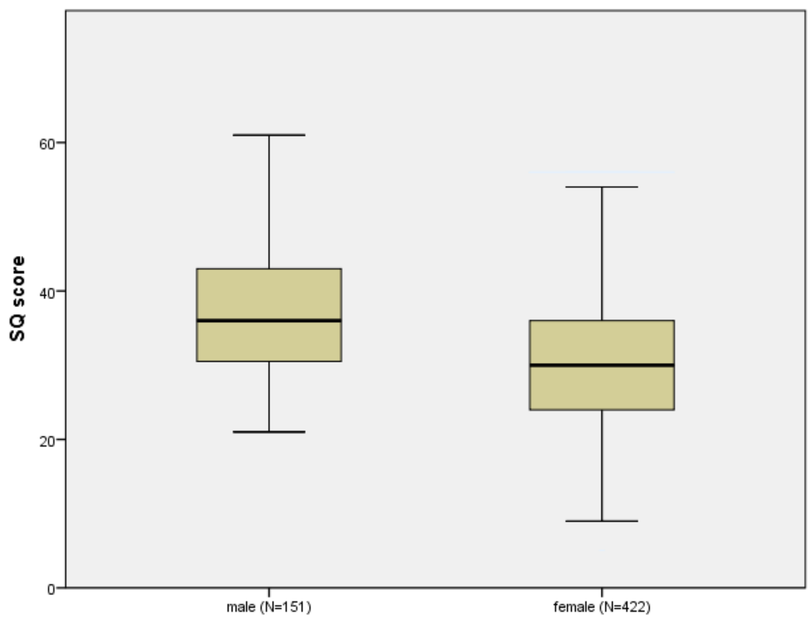


Figure 5.9 Box and whisker plot of median, min, max, range, IQR of SQ scores for males and females.

An effect of gender, U=27142.5, z=-3.068, p=.002 was found on the morality scale, with males scoring higher (mean=.91, SD=1.13) than females (mean=.62, SD=.98). Sepcifically, discriminative items (below the new significance level of .0125) were 1 ("I enjoy manipulating other people's feelings"), U=29607.5, z=-2.570, p=.010, r=.11 small effect; and 3 ("In today's world, I feel justified in doing anything I can get away with to succeed."), U=28607, z=-3.744, p=.000, r=.16 small effect. In both males scored higher than females, respectively: item 1 (males: mean=.17, SD=.44; females: mean=.10, SD= .37) and item 3 (males: mean= .20, SD=.48; females: mean= .07 , SD=.29).

On the cognitive tasks the only significant difference between males and females was on the MRT score, U=2074.5, z=-2.608, p=.009, r=.20, small effect; GEFT score, U=2276.0, z=-.2.460, p=.014, r=.20, small effect, and in the hacking challenge RT, U=1222.5, z=-2.309, p=.021, r=.20 small effect. In all these tasks males outperformed females (see descriptive statistics above).

A Kruskal-Wallis test revealed an effect of subject degree on the SQ, H(2) = 28.889, p=.000, and on the morality scale, H(2)=11.969, p=.003; but not on the novel scale-r: H(2)=.202, p=.904.

Mann-Whitney tests were used to follow up the finding; a Bonferroni –Holm correction was applied to avoid inflating Type I error. As for the SQ, participants with science background scored higher (mean=34.89, SD=9.931) than those with a social science background (mean=30.24, SD=9.160) and the difference was significant, U=26132.5, z=-4.955, p=.000 (threshold of p=.0167), r=.21, small effect. Participants with computer science background scored higher (mean=38.00, SD= 6.633) than those with a science background but the different was not significant, U=567, z=-1.119, p=.263. The other significant difference was between subjects with a computer science background and those with a social science background, U=733.5, z=-2.507, p=.012, (threshold of p=.025), r=.13 small effect.

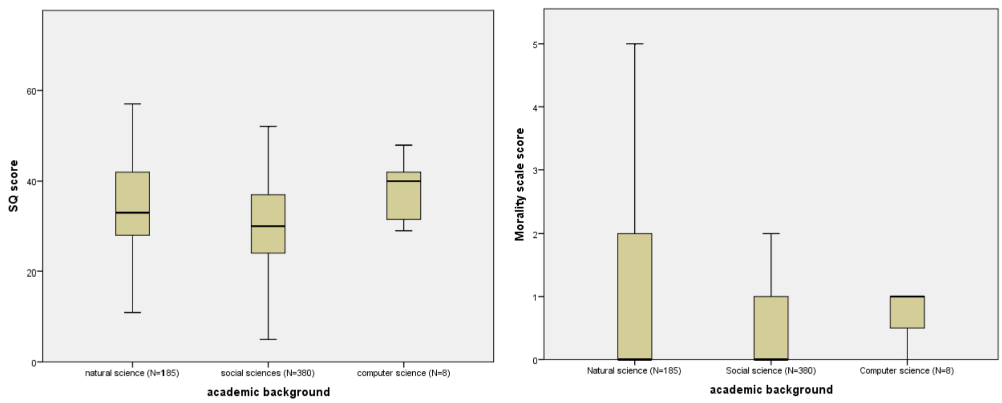


Figure 5.10 Box and whisker plots of median, min, max, range, IQR of SQ scores (left) and morality scale score (right) for academic background.

As for the morality scale the difference was between those with a science background and those with a social science background (new threshold of p= .016): moral scale, U=30187, z=-3.103, p=.002, r=.13 small effect. Differences within the novel scale items according to subject degree were also investigated. Significant differences were found on item 1 ("I enjoy manipulating other people's feelings"), H (2) =7.824, p=.02 and on item 3 ("In today's world, I feel justified in doing anything I can get away with to succeed"), H (2) =24.787, p=.000.

Mann Whitney revealed that differences were between social science background and science background on item 1, U=32730.5, z=-2.629, p=.009 (new threshold of p=.016), r=.11, small effect; item 3, W=31459, z=-4.156, p=.000 (new threshold of p=.0125), r=.17, small effect.

To check for a possible confounding effect of gender, the same analysis was run only with the male sample. Differences among the different academic backgrounds on the moral scale (H (2) =6.883, p=.032) and particularly on the item 3 (H (2) =13.489, p=.001) were still significant. For the morality scale total score, no significant differences were found comparing groups; while on item 3, significant differences were found between social science background and science background (U=2090.5, z=-3.206, p=.001 (new threshold of p=.0125), r=.27 small effect) and between social science background and computer science background (U=154, z=-3.335, p=.001 (new threshold of p=.0125), r=.37).

As for the subject degree the Kruskal-Wallis test revealed a significant effect for crucipuzzles score, H (2) =6.920, p=.021 and for hacking challenge RT, H (2) =11.816, p=.003. Mann- Whitney tests with Bonferroni-Holm corrections were run to investigate where the differences lied. The only significant difference was for the hacking challenge RT between natural science background (mean=5315.42 SD=2961.07) and social science background (mean=7229.29, SD=3550.91), U=1257.5, z=-3.440, p=.001 (new threshold of p=.0167) r=.30, small effect. Computer science background were slower than the other two groups (mean=8099.61, SD=8019.38).

No relations between self-rating of hacking skills or number of hacking activities and the morality scale, the novel scale-r, the SQ and the four components were found (Ling et al., 2009).

5.4.5 Bivariate correlations

Spearman's correlations were investigated for all the variables in order to look at patterns of relationships. The interest was to look whether self-report measures and cognitive measures of systemizing and attention to detail had a relationship with tasks representative of hacking skills in the general population and also with self-reported hacking skills. All significant correlations are reported below; however, after having applied a Bonferroni-Holm correction, few correlations still remained significant and are highlighted in bold. The starting threshold for significance is .002 (N=24).

Both the self-report rating of hacking skills (**Rho=.278, p=.000**) and the number of hacking activities performed (**Rho=.215, p=.000**) correlated with SQ. That is, individuals on the higher end of systemizing traits had also higher level of hacking expertise and performed a higher number of hacking activities.

The level of self-reported hacking skills correlated also positively with the novel scale-r (Rho=.106, p<.01). It also correlated positively with steganography score (**Rho=.231, p=.000**) and negatively with hack RT (Rho=-.175, p<.05).

The number of hacking activities performed correlated positively with the morality scale (**Rho=.150, p=.000**), which indicates that low levels of morality traits had a relationship with the hacking activities in which one engaged, with MRT score (**Rho=.297, p=.000**), Raven score (Rho=.192, p<.05), recognition task (Rho=.194, p<.05), steganography score (**Rho=.235, p=.002**) RT in the hacking task (Rho=-.260, p<.01). The finding that both the level of hacking expertise and the number of hacking activities performed correlated with performance on the steganography task and on the hacking challenge supported the initial choice to use these tasks as representative of hacking expertise.

SQ score correlated with the novel scale-r (**Rho=.359, p=.000**) and with steganography score (Rho=.194, p<.05), indicating that higher systemisers are better in decrypting an embedded message. The local bias correlated negatively with SQ (Rho=-.210, p<.05) and with the novel scale (Rho=-.213, p<.05). This indicates that those who have strong systemizing traits and/or are highly resourceful experience less local interference. No other correlations were found between SQ and novel scale-r with cognitive tasks.

The four factors of the SQ by Ling et al. (2009) did not show any significant correlation with all the other variables.

Correlations between hacking tasks and measures of field independency and mental rotation were found, whereas visual working memory task had no significant correlations with any other tasks:

- Steganography score had positive correlations with Raven score (Rho=.190, p<.05) and GEFT score (Rho=.191, p<.05), suggesting that better performance in decrypting a hidden message is related with a field independent cognitive style.
- RT (but not scores) on crucipuzzles correlated with MRT RT (**Rho=.311, p=.000**), with Raven RT (Rho=.217, p<.05) and GEFT RT (Rho=.213, p<.05); indicating that field independency and the mental rotation abilities have a positive relationship with the ability to find words in a matrix of letters.
- RT on the hacking challenge had negative correlations with Raven score (Rho=-.250, p<.01), MRT score (Rho=-.182, p<.05) and GEFT score (Rho=-.198, p<.05). It also had

positive correlations with GEFT RT (Rho=.247, p<.01). Again, this finding suggests a role of field independency and mental rotation in the ability to solve hacking challenges. However, given the significant gender differences found on the GEFT score, MRT score and hacking challenge RT, correlations involving those tests were re-analysed to avoid a possible confound.

- GEFT score did not have any significant correlations;
- MRT score still correlated with the steganography score (Rho=,341, p<.05);
- Hacking challenge RT consistently with what found in the previously analysis had significant correlations with the number of hacking activities (Rho=-.410, p<.05), the self-rating of hacking skills (**Rho=-.529, p=.001**), and GEFT RT (Rho=.454, p<.05). Additional correlations were found with the SQ (Rho=-.359, p<.05) and order score (Rho=-.428, p<.05). Interestingly, the correlation with SQ goes in the same direction as the correlation found between SQ and steganography in the total sample as it indicates a possible relationship between systemizing and hacking expertise. The correlation with the visual working memory task that required the temporal memory it is plausible as the challenge works on a sequence of progressive questions to be solved.

5.5 Discussion

Study 2 aimed at looking for patterns of correlations between hacking expertise, systemizing, field independence and two visuo-spatial abilities – mental rotation and visual working memory. Moreover, a correlation between morality traits and the involvement on hacking activities was investigated as well as the role of problem solving abilities in performance on hacking like tasks.

A preliminary PCA was conducted on the SQ to compare components' structure with results presented in the literature. Findings revealed that there were some communalities with the 18 items four factor model presented by Ling et al. (2009) but there were also differences in the loading of some items; specifically of the DIY factor; so our data did not fit perfectly into the model. A PCA analysis on the novel scale-r was performed to compare results with the ones obtained in Study 1; a 2-component structure was found in which items loaded differently from what found in Study 1.

Table 5.13 Comparison between component structure of the novel scale-r in Study 1 and Study 2

Table 5.13

*Comparison between component structure of the novel scale-r in Study 1 and Study 2 (reverse scored item are with an asterisk *)*

STUDY 1	
9 I am good at finding solutions to problems that other would not be able to solve	2: *I do not think it is necessary to find new solutions to a problem, if the one I have used in the past was successful
7 When I encounter a problem, I usually look at it from different perspectives in order to come up with the best solution	12: When I find a way to solve a situation I do not feel the curiosity to find another way to solve it
5 I believe that no matter what life throws at me, I will be able to handle it	10: *I do not feel comfortable with taking new perspectives into things
3 I would define myself as a type of person who thinks outside the box	
4 *I do not like learning new things	
1 I like trying new things	

STUDY 2	
8. *I do not feel comfortable with taking new perspectives into things (e.g. change my point of view, find alternatives…).	5. I believe that no matter what life throws at me, I will be able to handle it.
9. *When I find a way to solve a situation I do not feel the curiosity to find another way to solve it.	7. I am good at finding solutions to problems that other would not be able to solve.
4. *I do not like learning new things (e.g. at work and in my spare time).	2. I think it is necessary to find always new and better solutions to a problem, even if the one I have used in the past was successful.
6. *When I encounter a problem, I do not usually look at it from different perspectives in order to come up with the best solution.	1. I like trying new things (e.g. hobbies, activities).
3. *I would not define myself as a person who thinks out of	

Other PCAs performed with different samples revealed different patterns of items aggregation on the two components. In was then hypothesized that the novel scale might be considered a one-component scale measuring problem solving and resourcefulness/curiosity.

Differences on scores between groups were investigated. Consistent with the literature, gender differences were found in the SQ and in MRT and GEFT; tasks that are known in the literature for showing male advantage. In the hacking tasks, the only difference was in the hacking challenge reaction times in which males were faster than females. It is likely that this task showed a male advantage too, given that within hackers males are more represented than females. Also in line with the literature, participants with a science background scored higher than participants with a social science background on the SQ. Interestingly, those with a computer science background had the higher scores compared with natural science, even if the difference failed to reach the level of significance. The four factors provided by Ling et al. (2009) did not add any discriminative value to the SQ either as regards gender, academic background and self-reported level of hacking expertise or number of hacks performed. An effect of gender was found on the morality scale with males reporting lower levels of morality; an effect of the academic background was also found and was not mediated by sex. Those with a science and with a computer science background reported higher scores on the item “I enjoy manipulating other people’s feelings” than those with a social science background.

Among all the cognitive tasks, the only one in which a significant difference was found was in the reaction times of the hacking challenge in which natural science background were faster than social sciences background. Both the self-report measures had significant correlation and this means that problem solving skills and resourcefulness are linked to systemizing ability. Self-report level of hacking skills and number of hacking activities performed both correlated with SQ, indicating that individuals with high self-reported systemizing traits are also those with high self-reported hacking skills. The correlation between the self-report rating of hacking expertise with steganography and the hacking challenge gave objective support to their level of expertise. SQ correlated with steganography, i.e. those who were better in the decryption task were those with higher scores on the SQ. Contrary to what previously found in the literature (Billington et al., 2008) the results indicated that high systemizing ability is related with the ability to resist local interference. The implications of the results found in this study will be discussed in Chapter 7 and contrasted with those findings presented in literature.

The correlation between the hacking tasks and measures of mental rotation ability (MRT) and field independency (GEFT) supported the idea of a role of this ability and cognitive style in hacking expertise, as predicted. When considering only the male sample, the role of field independence was found on the crucipuzzles and the hacking challenge, but not on the steganography task. Vice versa, the role of mental rotation ability was found in the steganography but not in the crucipuzzles and the hacking challenge. Moreover, while no correlations were found with the visual working memory task in the total sample, when analysing only males, results indicated a relationship between performance in hacking task and in in the order recognition task, as well as between the performance on the crucipuzzles and serial recognition task. Scores on the moral scale (the higher the scores the lower the morality traits) correlated positively with the number of hacking activities performed, and this was in line with the initial hypothesis discussed in this Chapter.

Study 2 represented the investigation of the relationship between systemizing traits and hacking expertise as well as possible correlations between hacking performance and certain cognitive tasks. The target population was in this case the general population, and it was administered to Italian people because I am Italian and I had far more contacts in Italy than elsewhere. Study 3 described in the next chapter applied the same rationale of Study 2 to a sample of hackers. The objective was to compare results found in both study and to look for differences between hackers and general population. Chapter 6 will first describe Study 3 in terms of participants, methods, data analysis and discuss the findings. Given the substantial similarity of Study 2 and Study 3, in the final paragraph of the next chapter (6.4.6) analyses on the combined datasets are discussed.

6 STUDY 3 – Exploring the relationship between hacking tasks and measures of systemizing in hackers vs. non hackers

6.1 Introduction

Study 3 shared the same rationale of the Study 2 discussed in Chapter 5. Study 2 aimed at looking for individual differences and correlations pattern between hacking expertise, systemizing, problem solving, morality traits, and cognitive measures such as MRT, GEFT, the Navon task, Raven and visual working memory task in the general population. In Study 3 the same rationale was addressed to a cohort of hackers, compared to non-hackers. The hypothesis beyond Study 3 was that hackers might report higher scores on measures of systemizing, problem solving and lower morality traits compared to the non-hackers. Moreover, given the hypothesized role of certain cognitive skills and cognitive styles on hacking expertise discussed in Chapters 2 and 3, the aim of the present study was to investigate individual differences between hackers and non-hackers in those cognitive tasks. In the initial design of Study 3, as a mean to assess for hacking expertise among hackers, a Capture the Flag (CTF) challenge was added to the battery of tests. Even if the battery still comprised the hacking-like tasks developed to assess hacking expertise in non-hackers, the additional CTF would have been a more precise and targeted task to evaluate performance in hackers. Indeed, the CTF comprised a group of specialised tests – i.e. SQL injection, Cookie, Enumeration – that were developed to mirror specialized hacking tasks. The CTF id described in section 6.2.2 below and the description and explanation of all the challenges included is reported in Appendix F. Unfortunately, it was not possible to use data from the CTF for the analyses as none of the hackers who took part in the CTF (N=40) volunteered to complete the first or the second part of Study 3.

6.2 Methods

6.2.1 Participants

460 participants completed the first part of the study. Participants under 18 and above 60 years old were excluded, as well as participants with learning disabilities.

Extreme outliers were identified and removed according to the outlier labelling rule (Hoaglin, et al., 1986). After this initial cleaning, data from 349 participants were retained for the analysis for the first part of the study. 160 participants were males (45.8%) and 183 were females (52.4%); 6 participants indicated “other” as gender (1.7%). Age ranged from 18 to 60 (mean =28.48, median=26, SD=8.48). 104 participants were hackers, and 245 participants were non-hackers. Inclusion criteria in the hacking group were either attending an ethical hacking degree, or working as an ethical hacker or in other fields but having engaged in more than 5 hacking activities listed in the questionnaire. As for the academic background 80 participants were from natural sciences (22.9%), 110 from social sciences (31.5%), 40 from finance/business (11.5%), 43 from computer science (12.3%) and 76 from ethical hacking (21.8%). Of those who left their email at the end of the first part (N=293), 132 started the battery. Of these, 77 (16 hackers and 61 non-hackers) completed the whole battery and 132 completed only some tasks resulting in different sample sizes for each task: 114 (24 hackers and 90 non-hackers) for MRT, 119 (26 hackers and 93 non-hackers) for Raven task, 122 (27 hackers and 95 non-hackers) for the visual working memory task, 114 (23 hackers and 91 non-hackers) for the GEFT, 100 (20 hackers and 80 non-hackers) for the Navon task, 118 (27 hackers and 91 non-hackers) for the hidden word search task, 91 (19 hackers and 72 non-hackers) for the hacking challenge. It was not possible to use data from the steganography task as only 2 participants out of 133 were able to decrypt the message in the time allowed.

Among the 16 hackers who completed the whole battery, 3 were females and 13 were males. 5 reported having performed 1 hack, 3 reported 2 hacks, 1 reported 3 hacks, 2 reported 4 hacks, 2 reported 7 hacks, 2 reported 9 hacks and 1 reported 12 hacks. As regards the self-rating of hacking skills, 5 hackers reported 1, 3 hackers reported 2, 7 reported 3 and only 1 hacker reported 5. There was no relationship between the will to complete the battery and took part in the experiment and the self-reported hacking proficiency or the number of hacks completed.

The study was approved by the Ethics Committee of the School of Social and Health Sciences at Abertay University (see Appendix B).

6.2.2 Apparatus and Stimuli

Apparatus was the same used for Study 2 as regards the questionnaires and the battery of cognitive tests. The stimuli used were the same as for the Study 2, the only task that differs was the crucipuzzle task which was replaced by a picture word search task because the English version of a crucipuzzle was not available. As discussed in the Introduction the CTF was added to Study 3. It was administered online on a platform developed ad-hoc. The developed system consisted of two Virtual Machines with different functions: 1) the Virtual Machine running the CTF Scoring software which contains the challenges and manages the flags that the participants capture, and 2) the Virtual Machine that the participants attack in order to complete the challenges. The target virtual machine is UBUNTU based and runs Apache2, MySQL and PHP Version 5.2.4-2.

Picture word search task

Participants were presented with an image and their task was to find 6 meaningful words hidden in it. The picture was presented at the centre of the screen and participants had to type one word at a time, then press enter. The response was followed by a positive or negative feedback. There were five different versions of this task, i.e. five different pictures used with different words hidden – randomly selected by the software. Time limit for the task was 5 minutes. The maximum score achievable for this task was 6. One example of the task is given below; in the picture, the six hidden words are: mirror, couch, straw, tiles, cat, cord. Number of correct words found and mean reaction times for each correct recognition were logged.

Figure 6.1 Example of stimuli used in the hidden words search task

CTF

This task was developed in collaboration with ethical hackers partly as a research tool for this study and partly as a teaching and learning tool. A CTF system is a set of challenges where the objective is to gain a flag of some sort; generally it is a string or a hash that is presented to the challenger on completion of a task. The CTF system used for this study involved a variety of categories all of which have their own task and aimed at measure participants' knowledge of and ability to address typical problems found in computer security testing. The system was developed as a virtual machine and contains applications that can be probed for vulnerabilities. On successful exploitation of a vulnerability, the subject was presented with a flag in the form of a token that can be entered to the scoreboard. Submitting the correct flag proved that the task has been completed. The challenges are all web-application based and there are four web applications that can be attacked to complete the challenge.

1. Abertay Hackstore that is a mock-up of a merchandise store where participants can browse available products (e.g. clothing and gifts).
2. Hacktay Bank that mirrors a banking application.
3. Abertay Hacklab Auction that mirrors an on-line auction application.
4. Abertay Hacklab Forum that is a vulnerable forum application where it is possible to post messages.

CTF challenges belong to different categories: cookies, enumeration, injection, basics. An HTTP cookie (simply known as cookie) is a small piece of data that a server sends to the user's web browser. It remembers stateful information for the stateless HTTP protocol. Cookies are mainly used for these three purposes: 1) session management (user logins, shopping carts), 2) personalization (user preferences), 3) tracking (analyzing user behavior). Enumeration is the process of sequentially operating on elements of an object—typically a collection—each at most once, one at a time in turn. Code injection is the exploitation of a computer bug that is caused by processing invalid data. Injection is used by an attacker to introduce (or "inject") code into a vulnerable computer program and change the course of execution. A detailed description step by step of the CTF challenges is reported in Appendix G.

6.2.3 Procedure

Procedure was the same as for Study 2, except for the fact that in this study participants who completed the questionnaires and the battery of cognitive tasks received a £10 Amazon voucher. This was aimed to represent an incentive especially for hackers, to gather as many of them as possible. The order of the tasks was randomized between participants.

6.3 Data analysis

As for Study 2, the present study adopted a correlational approach with a between subject design. Questionnaire's scores, number of correct responses and reaction times (for correct responses) were measured for the behavioural tasks and treated as dependent variables. An initial cleaning of the raw data was performed as for the previous study. Extreme outliers were identified and removed according to the outlier labelling rule (Hoaglin, et al., 1986). Descriptive statistics were first calculated for all the variables, and parametric assumptions were checked. Correlations were obtained for all the variables and mean differences with different grouping variables were investigated. As for the previous study, also in the present one parametric test assumptions were not met so non-parametric tests were used for mean differences and correlations as explained in the following paragraphs. Before that, Principal Component Analyses on the novel scale-r, SQ and the morality scale were performed to compare the results with the ones obtained in Study2.

6.4 Results

6.4.1 Descriptive statistics

Of the non-hackers (N=245), participants had never performed any hacking activity. Among the hackers (N=104) the following numbers of hacking activities were reported: 18 reported 1 hack, 12 reported 2 hacks, 14 reported 3 hacks, 12 reported 4 hacks, 15 reported 5 hacks, 9 reported 6 hacks, 6 reported 7 hacks, 9 reported 8 hacks, 5 reported 9 hacks, 1 participant reported 11 hacks and 3 participants reported 12 hacks. Within the hackers group, males reported more hacking activities (mean=4.93, SD=2.9, median=5, IQR=4) than females (mean=3.13, SD=2.27, median=3, IQR=3).

As for the self-report level of hacking skills on a scale from 0 to 5, among the hackers group, 24 reported 1, 29 reported 2, 34 reported 3, 14 reported 4 and 3 reported 5. Males reported similar self-ratings of hacking skills (mean=2.48, SD=1.2, median=3, IQR=1) than females (2.14, SD=1.2, median=2.5, IQR=2)

SQ scores ranged from 4 to 70 (mean = 33.04, median = 33, SD=12.83). Novel scale-r scores ranged from 0 to 18 (mean=9.81, median=10, SD=3.86), Morality scale scores ranged from 0 to 7 (mean=1.09, median=1, SD=1.40).

The Navon local interference effect was found also in the present study. Mean RT in the local condition for the total sample was slower (mean=674.35, SD=157.1) than in the global condition (mean=558.4, SD=107.5). The mean accuracies in the global condition was higher (mean=94.3, SD=9.5) than the mean accuracies in the local condition (mean=61.2, SD=17.13). On reaction times, the global bias was bigger (mean=8.2, SD=125.7) than the local bias (mean=-1.0, SD=65.3) indicating that overall participants experienced the effect of local level distractors. Statistics for questionnaires and the cognitive tasks based on gender and on hackers vs. non-hackers are reported in the tables below[19].

[19] Participants who indicated other were not included in the descriptive statistics

Table 6.1 Descriptive statistics for cognitive measure for males and females.

Table 6.1
Descriptive statistics for cognitive measure for males and females.

	MALES				FEMALES			
	Mean (s.e.)	**Median**	**St. Dev.**	**IQR**	**Mean (s.e.)**	**Median**	**St.Dev**	**IQR**
SQ	37.91 (.91)	38	11.55	16	28.6 (.92)	28	12.46	15
N	160				183			
Novel scale-r	10.18 (.29)	10	3.73	5	9.46 (.29)	10	3.99	5
N	160				183			
Morality scale	1.27(.17)	1	1.48	2	.94 (.09)	0	1.33	1
N	160				182			
MRT score	17.39 (.57)	18.5	4.25	7	17.12 (.62)	18	4.71	8
N	54				57			
MRT RT	2913.30 (166.68)	2888.4	1224.85	1721.63	2942.73 (166.65)	2991.26	1258.16	1622.88
Raven score	6.02 (.25)	6	1.85	2	5.76 (.26)	6	1.97	3
N	57				59			
Raven RT	15875.90 1192.94	15175.25	9006.47	14538.24	15547.04 1350.01	13131.37	10369.65	14571.33
Recognition score	11.24 (.29)	11	2.21	4	11.56 (.27)	11	2.15	3
N	58				61			
Recognition RT	1735 (247.28)	1403.89	1883.24	850.56	1571.36 (78.12)	1495.08	610.10	999.06
Order score	16.95 (.43)	17.5	3.27	4	16.7 (.37)	17	2.91	4
N	58				61			
Order RT	2060.65 (107.07)	2049.71	815.42	1058.71	1957.88 (88.48)	1959.21	691.09	923.98
GEFT score	15.91 (.53)	18	3.83	3	15.17 (.54)	17.5	4.17	4
N	53				58			
GEFT RT	14055.08 (666.5)	14410.25	4852.62	8192.36	15481.73 (586.28)	16152.46	4464.96	6539.35
Navon local mean RT	650.2 (22.11)	639.2	153.18	202.9	6969.62(22.02)	699.92	158.84	200.24
N	48				52			
Navon global mean RT	541.07 (13.3)	517.45	92.36	125.8	574.42 (16.43)	545.89	118.49	145.33
Global bias	-3.57 (23.16)	6.22	133.04	123.40	20.28 (20.95)	7.5513	118.55	149.24
N	33				32			
Local bias	.58 (9.59)	6.75	66.43	70.21	-2.48 (9.01)	-7.01	64.91	74.76
N	48				52			
Local/Global precedence	109.15 (22.92)	93.94	158.77	143.27	122.2 (18.84)	85.11	135.89	196.97
N	48				52			
Hidden words search score	4.56 (.184)	5	1.39	2	4.19 (.18)	4	1.38	2
N	57				58			
Hidden words search RT	17694.46 (1456.31)	13616	10994.89	17722	19052.94 (1919.38)	16739.67	14617.58	16115.22
Hacking challenge score	4.69 (.54)	4	3.71	7	4.24 (.46)	3	2.98	6
N	48				41			
Hacking challenge RT	6883.18 (727.32)	4997.30	5039.05	5583.88	6784.97 (563.13)	6040	3605.78	4220.85

Table 6.2 Descriptive statistics by cognitive measure for hackers and non-hackers.

Table 6.2
Descriptive statistics by cognitive measure for hackers and non-hackers.

	NON-HACKERS				HACKERS			
	Mean (s.e.)	**Median**	**St.Dev**	**IQR**	**Mean (s.e.)**	**Median**	**St.Dev**	**IQR**

SQ **N**	30.17 (.79) 245	30	12.41	17	39.82 (1.09) 104	39	11.18	15.75
Novel scale-r **N**	9.62 (.25) 245	10	3.89	5	10.28 (.36) 104	10.5	3.75	5.75
Morality scale **N**	.89 (.08) 245	0	1.36	1	1.55 (.14) 104	1	1.39	2
MRT score **N**	17.84 (.47) 90	19	4.46	7	15.54 (.82) 24	15	4.04	5
MRT RT	3091.48 (122.59)	3039.98	1163.06	1454.92	2362.50 (266.53)	2276.87	1305.75	1935.27
Raven score **N**	6.12 (.19) 93	7	1.89	3	5.12 (.35) 26	5	1.79	3
Raven RT	16059.88 (1039.22)	14254.12	10021.87	15591.25	14646.04 (1571.08)	13914.03	8010.97	10196.46
Recognition score **N**	11.42 (.22) 95	11	2.12	3	11.41 (.44) 27	12	2.3	4
Recognition RT	1735.72 (153.84)	1555.75	1499.45	979.06	1324.45 (123.19)	1288.07	640.13	447.6
Order score **N**	16.8 (.31) 95	17	3.04	4	16.96 (.62) 27	18	3.23	6
Order RT	2047.29 (79.6)	2060.06	775.82	1072.3	1907.74 (123.44)	1868.94	641.41	734.72
GEFT score **N**	15.79 (.41) 91	18	3.91	3	14.78 (.88) 23	16	4.25	7
GEFT RT	14465.6 (494.48)	14414.52	4717.12	7904	15863.84 (882.23)	15661.32	4231.03	6667.21
Navon local mean RT **N**	687.33 (18.15) 80	667.69	162.32	216.29	622.42(27.8) 20	650.62	124.49	234.44
Navon global mean RT	562.5(12.02)	532.38	107.78	129.35	541.9(24.07)	519.96	107.67	100.29
Global bias **N**	22.54 (14.38) 49	6.22	100.69	133	-35.82 (44.88) 16	-9.27	179.54	301.54
Local bias **N**	7.52 (6.4) 80	6.21	57.26	68.6	-35.15 (18.8) 20	-14.72	84.09	87.64
Local/global precedence **N**	124.79 (15.99) 80	15.99	143.03	144.88	80.51 (35.66) 20	86.58	159.49	230.9
Hidden words search score **N**	4.45 (.14) 91	5	1.32	2	4.15 (.3) 27	5	1.56	2
Hidden words search RT	18302.69 (1410.37)	14318.5	13454.15	15690.2	18529.84 (1978.68)	16228.66	10281.57	17478.5
Hacking challenge score **N**	4.6 (.4) 72	3.5	3.45	6	3.84 (.69) 19	2	3.02	5
Hacking challenge RT	6607.14 (518.49)	5259.05	4399.56	3667.97	7546.93 (1006.85)	6683.6	4388.74	7167.71

6.4.2 Parametric assumption check

Parametric assumptions were first checked for all the tasks and the questionnaires according to gender by group and the relevant statistics are reported in the tables E1 and E2 in Appendix E. **E2222** Parametric assumptions were not met, as mean and median were not similar in for all tasks, even if the standard deviations were smaller than the means. Values of skeweness and kurtosis indicated a non-normal distribution for the majority of tasks and normality tests confirmed a deviation from a normal distribution (see figures in Appendix E). Levene's test (untransformed) proved homogeneity of variances for males and females but not for hackers and non-hackers in the Navon task and in the GEFT. For all the above mentioned consideration, non-parametric tests were then used to investigate mean comparisons (Mann-Whitney test) and correlations (Spearman's Rho).

6.4.3 Principal Component Analyses

Several PCAs were conducted to investigate similarities and differences between results from the present study and findings from Study 2 presented in Chapter 5. The aim of the PCAs was either to compare results between studies and with those reported in the literature, discussed in Chapter 5; but also to investigate whether latent construct that were possibly found were discriminative between hackers and non-hackers; and/or showed correlations with measures of hacking expertise. In Study 2 it was found that the four components found by Ling et al. (2009) did not correlate with hacking performance; in this study the analyses were replicated to look for similarities and differences in the results. First, the 18 items model proposed by Ling et al. (2009) was tested to see whether it was a good fit for the data. Second, given the inconclusive results from the previous component analyses conducted on the novel scale-r, a PCA was conducted to add some information and clarify the structure of the scale. No more PCAs were conducted on the novel scale-r and the SQ as findings from Study 1, replicated in Study 2, confirmed that the instrument measures construct different from the SQ.

6.4.3.1 **PCA on the SQ**

To make a comparison with the Ling et al.'s (2009) results and with those from Study 2, a PCA on the 18 items of the short SQ version provided by Ling et al. (2009) was conducted imposing an extraction of 4 components. The cumulative variance (49%) was slightly above the one obtained in Study 2 (44%) . The four components had different Eigenvalues as in Study 2 component 1 had an Eigenvalue of 3.63 and explained 20% of variance, component 2 had an Eigenvalue of 1.72 and explained 9% of the variance, component 3 had an Eigenvalue of 1.37 and explained almost 8% of the variance, and component 4 had an Eigenvalue of 1.2 and explained 6.6% of the variance.

Table 6.3 Pattern Matrix of the 18 item SQ version (Ling et al., 2009)

Table 6.3
Pattern Matrix of the shortened 18 items version of the SQ

	Component			
Item	**1**	**2**	**3**	**4**
SQ20	.788			
SQ33	.760			
SQ5	.656			
SQ43	.643			
SQ11	.641			
SQ40	.403			
SQ7	.360			
SQ48		.772		
SQ45		.695		
SQ15		.565		
SQ51		.466		
SQ31			.858	
SQ24			.641	
SQ49			.484	
SQ18			.422	
SQ26				.696
SQ35				.645
SQ37				.450

Table 6.4 Structure matrix of the 18 item SQ version (Ling et al., 2009)

Table 6.4
Structure Matrix of the shortened 18 items version of the SQ

	Component			
Item	**1**	**2**	**3**	**4**
SQ20	.763			
SQ33	.743			
SQ5	.654			
SQ11	.632			
SQ43	.571			
SQ40	.503			
SQ7	.501			
SQ48		.706		
SQ45		.657		
SQ15		.593		
SQ51		.579		
SQ31			.796	
SQ24			.726	
SQ49			.577	
SQ18			.572	
SQ26				.713
SQ35				.621
SQ37				.593

The distribution of items is more similar to the Ling et al.'s (2009) than the one obtained in Study 2. Only three items loaded differently from their study. Item 18 ("I find it difficult to understand instruction manuals for putting appliances together") loaded on the topography component, consistent with Study 2. Items 26 ("When I look at a piece of furniture, I do not notice the details of how it was constructed") and 37 ("When I look at a building, I am curious about the precise way it was constructed" that loaded on the same component with item 35 ("I am not very meticulous when I carry out D.I.Y") while in Ling et al.'s (2009) study they loaded on to the Structure component.

Table 6.5 Comparison between factors' structure of the shortened 18 items version of the SQ (Ling et al., 2009) and components' structured obtained in Study 2 and in the present study.

Table 6.5
Comparison between factors' structure of the shortened 18 items version of the SQ (Ling et al., 2009) and components' structured obtained in Study 2 and in the present study.

Component	Author(s)	Items
Technicity	Ling et al. (2009)	5, 11, 20, 33, 40, 43
Component 1	Study 2	5, 11, 20, 33
	Study 3	5, **7**, 11, 20, 33, 40, 43
Topography	Ling et al. (2009)	24, 31, 49
Component 2	Study 2	18, 24, 31, 40, 49
	Study 3	**18,** 24, 31, 49
Structure	Ling et al. (2009)	15, 26, 37, 45, 48, 51
Component 3	Study 2	**7**, 15, 26, 37, 48, 51
	Study 3	15, 45, 48, 51
DIY	Ling et al. (2009)	7, 18, 35
Component 4	Study 2	35, 45, 43
	Study 3	**26**, 35, **37**

Data from the present study seemed to confirm the components structure proposed by Ling et al. (2009) with the exception of just three items, but this might be due to the type of analysis performed here compared to the factorial analysis used by the authors in their study. In the following analyses, individual differences on the four components between hackers and non-hackers, as well as possible correlations with hacking expertise were investigated (see section 6.4.4).

6.4.3.2 **PCA on the novel scale-r**

A PCA was conducted on the novel scale-r to compare results with those obtained in Study 1 and Study 2. Two components were extracted with eigenvalues above 1. The first component explained 35% of the variance and the second component explained 12%, for a cumulative variance of 47%. In Study 1 the first component explained 35% of the variance (Eigenvalue=3.15), the second component explained 13% of the variance (Eigenvalue=1.21) and together explained 48% of the variance. In Study 2 the first component explained 30% (Eigenvalue=2.72) and the second component explained 12% of the variance (Eigenvalue=1.09). The total variance explained by the two components in Study 2 was 42%.

The pattern matrix and structure matrix (tables 6.6, 6.7) showed a two components' structure, in which items loaded differently in the two components compared to what found in the previous studies. Consistently with Study 1 and Study 2, most items have shared variance between the two factors and this might be indicative that the scale could be considered as a one factor scale measuring the construct of problem solving. In Study 1 (r=.418), Study 2(r =.404) and the present study (r=.462) the correlation between two components was consistent.

Table 6.6 Pattern Matrix of the novel scale-r

Table 6.6
Pattern Matrix of the novel scale-r

Item	Component	
	1	2
9	.738	
7	.726	
3	.650	
2	.647	
5	.353	
1		.845
8		.731
4		.691
6		.442

Table 6.7 Structure Matrix of the novel scale-r

Table 6.7
Structure Matrix of the novel scale-r

Item	Component	
	1	2
3	.693	
9	.685	
7	.682	
2	.672	
5	.449	
1		.748
4		.744

8	.742
6	.577

The components structure obtained in the present study is reported in the table 6.8 below

Table 6.8 Components' structure of the novel scale-r.

Table 6.8
Components' structure of the novel scale-r.

	COMPONENTS	Loadings
1	9 *When I find a way to solve a situation I do not feel the curiosity to find another way to solve it.	.738
	7 I am good at finding solutions to problems that other would not be able to solve.	.726
	3 *I would not define myself as a person who thinks out of the box.	.650
	2 I think it is necessary to find always new and better solutions to a problem, even if the one I have used in the past was successful.	.647
	5 I believe that no matter what life throws at me, I will be able to handle it.	.353
2		
	1 I like trying new things (e.g. hobbies, activities).	.845
	8 *I do not feel comfortable with taking new perspectives into things (e.g. change my point of view, find alternatives)	.731
	4 * I do not like learning new things (e.g. at work and in my spare time).	.691
	6 *When I encounter a problem, I do not usually look at it from different perspectives in order to come up with the best solution.	.442

The different loadings of the items on to the two components is summarized in table 6.9 and revealed no consistent pattern in the aggregation of the items.

Table 6.9 Comparison between components' structure of the novel scale-r between Study 1, Study 2 and the present study.

Table 6.9
Comparison between components' structure of the novel scale-r between Study 1, Study 2 and the present study.

Component 1	Study 1	1, 3, 4, 5, 6
	Study 2	3, 4, 6, 8, 9
	Study 3	2. 3. 5. 7. 9
Component 2	Study 1	2, 8, 9
	Study 2	1. 2. 5. 7
	Study 3	1. 4. 6. 8

A Maximum Likelihood analysis showed a Goodness of fit index of χ^2 (27) = 92.954, p=.000 for a one component model; which was better compared to the statistics obtained for a two components' model: χ^2 (19) = 53.072, p=.000. As no clear components were found in the novel scale-r, the possible relations with hacking expertise and differences between hackers and non-hackers will be investigated considering the scale as a whole.

6.4.3.3 **Combined PCAs on the SQ and the novel scale**

As for the previous Study 2 (see section 5.4.3.4), a PCA was conducted with all items of the SQ and the novel scale-r. The analysis was motivated by the fact that I wanted to compare the results obtained in Study 2 with the ones obtained in Study 3. As for the novel scale-r alone, also the combined analysis showed a different pattern of aggregation compared to Study 2. Items 3,9,2,8,6,4,7 of the novel scale-r together formed component 2 (see appendix E, table E3). Item 1 of the novel scale loaded on to component 7 with item 35 ("I am not very meticulous when I carry out DIY) and item 26 ("When I look at a piece of furniture I do not notice the details of how it was structured"). Item 5 of the novel scale loaded on to component 10 together with item 40 ("I find it difficult to understand information the bank sends me on different investment and saving systems").

6.4.4 Score comparisons between groups

On average, males (M=37.91, SD=11.55) scored higher than females (M=28.60, SD=12.46) in the SQ and the difference was significant U=8192.5, z=-7.040, p=.000, r=.14, small effect.

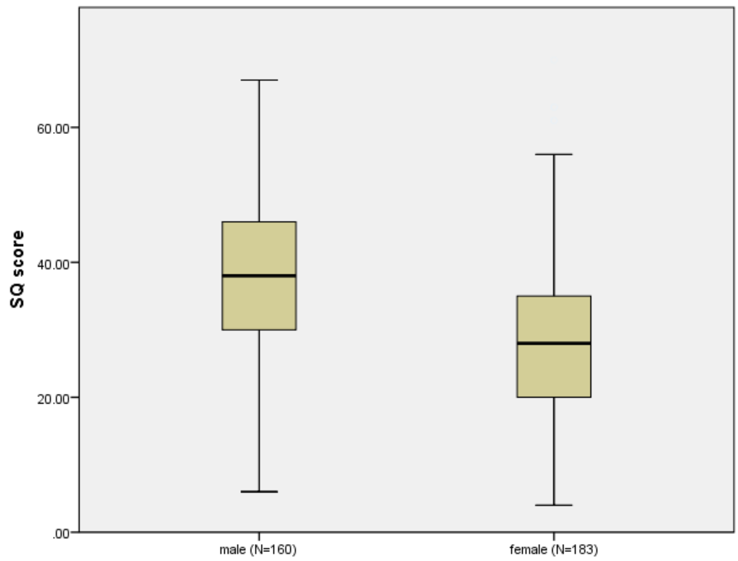


Figure 6.2 Box and whisker plot with median, min, max, range and IQR of SQ scores for males and females.

No gender differences were found on the novel scale-r, U=12935, z=-1.787, p=.074, and on the morality scale, U=4213.5, z=8218.5, z=-.658, p=.494. No other gender differences were found on the cognitive tasks, even when eliminating the hacker group from the analyses.

Significant differences were found between hackers and non-hackers in the SQ, U=7079.5, z=-6.568, p=.000, r=.35, medium effect; with hackers scoring higher (mean=39.82, SD=11.18) than non-hackers (mean=30.17, SD=12.41). Difference was still significant when considering only the male sample, U=2519.5, z=-2.322, p=.020, r=.18 small effect.

Significant differences were found also on three of the four factors found by Ling et al. (2009) (new minimum level of threshold = .0167): technicity, U=7230.5, z=-6.416, p=.000, r=.34 medium effect; topography, U=7975, z=-5.596, p=.000, r=.29, medium effect; structure, U=8288.5, -5.201, p=.000, r-=.28, small effect. In all three factors hackers scored higher than non-hackers: technicity (hackers: mean=8.16, SD=2.74; non-hackers: mean=5.68, SD=3.18), topography (hackers: mean=3.84, SD=1.62; non-hackers: mean=2.69, SD=1.76); structure (hackers: mean=4.63, SD=2.62; non-hackers: mean=3.04, SD=2.56). Considering only the male sample, significant differences were found on technicity, U=2548.5, z=-2.236, p=.025 and DIY, U=2597.5, z=-2.095, p=.036 but they failed to reach the new level of significance after Bonferroni-Holm correction.

The novel scale-r was not able to discriminate among hackers and non-hackers.

On the morality scale hackers scored higher (mean=1.55, SD=1.39) than non-hackers (mean=.89, SD=1.36) and the difference was significant, (U=8636.5, z=-5.018, p=.000, r=.27 small effect), even when controlling for sex, U=2097, z=-3.937, p=.000, r=.25 small effect. Differences on each item were investigated and they were significant on two items with hackers scoring higher than non-hackers (new threshold of significance =.0125): item 1 (“I enjoy manipulating other people’s feelings”), U=10777.5, z=-3.195, p=.001, r=.17 small effect; and item 3 (“In today's world, I feel justified in doing anything I can get away with to succeed), U=9975, z=-4.258, p=.000, r=.23 small effect.

The aggregated score of the SQ, morality scale and novel scale showed significant differences between hackers and non-hackers, U=7370.5, z=-6.152, p=.000, r=.33, medium effect with hackers reporting higher scores (mean=51.65, SD=13.5) on the total questionnaire than non-hackers (mean=40.7, SD=14.8). Nevertheless, it does not seem to add much discriminative value compared to the difference found in the SQ alone.

Other significant differences were found on the MRT score, U=747.00, z=-2.322, p=.020, r=.22 small effect; on the MRT RT, U=712, z=-2.558, p=.011, r=.24 small effect; on the Raven score, U=832.5, z=-2.459, p=.014, r=.22 small effect; on the serial recognition RT, U=952, z=-2.038, p=.042, r =.18 small effect; and on the local bias, U=569, z=-1.991, p=.047, r=.19 small effect. Differences on the MRT and on the Raven score were significant even when controlling for sex. After applying Bonferroni-Holm correction the differences that still remained significant were on the SQ and on the local bias. This means that hackers experienced less local interference, as the local bias is a measure of the effect of local distractors during the global condition of the Navon task (mean=-35.15, SD=84.09) than non-hackers (mean=7.52, SD=57.26).

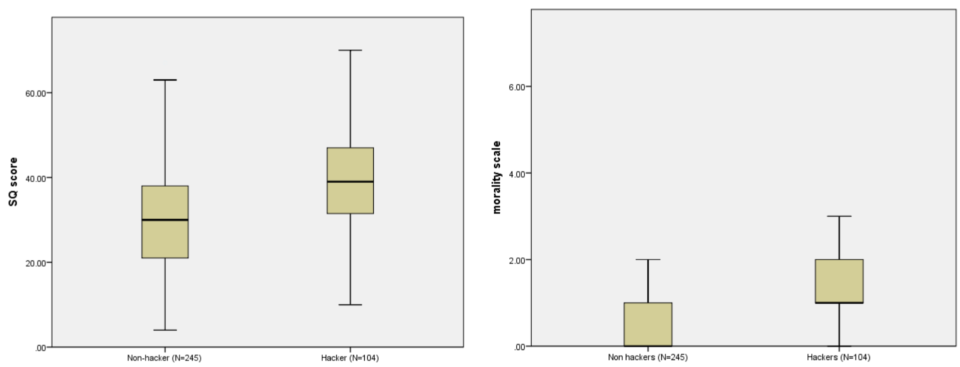


Figure 6.3 Box and whisker plot of median, min, max, range, IQR of SQ scores (left) and morality scale (right) for hackers and non-hackers.

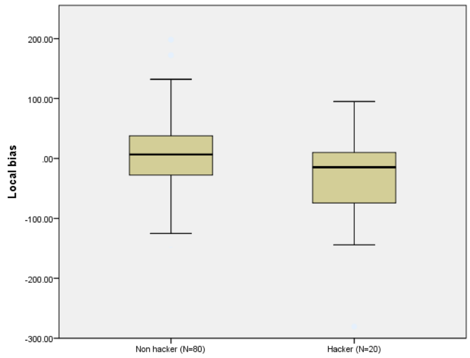


Figure 6.4 Box and whisker plot of median, min, max, range, IQR of local bias for hackers and non-hackers.

Differences between hackers (N=104) and programmers (N=28) in all tasks were also investigated and the analysis revealed significant difference in the SQ, U=910.5, z=-2.986, p=.003, r=.26 small effect; scores were higher for hackers (39.89, SD=11.20) than programmers (mean=33.71, SD=7.69). On the four components proposed by Ling et al. (2009), significant differences (new minimum level of threshold p= .0125) were found on topography, U=1012, z=-2.460, p=.014, r=.21 small effect; and on structure, U=955, z=-2.751, p=.006, r=.24, small effect. A significant difference was found also on the morality scale, U=956.5, z=-2.819, p=.005, r=.25 but not on the novel scale-r.

The other significant difference between hackers and programmers was on the Raven score, U=70, z=-2.88, p=.004, r=47, large effect, where programmers had a better performance (mean=6.86, SD=1.819) than hackers (mean=5.04, SD=1.791). However when applying Bonferroni-Holm correction for multiple comparisons, the difference on the Raven score was slightly above the significance level of p=.003.

Differences were found also between hackers and programmers in the SQ, with hackers scoring higher than the latter ones but they failed to reach the new significance level: item 13 ("I am fascinated by how machines work."), U=623, z=-2.492, p=.013; item 24 ("I find it difficult to read and understand maps", reverse scored), U=598, z=-2.713, p=.007; item 53 ("When I am walking in the country, I am curious about how the various kinds of trees differ"), U=576.5, z=-2.707, p=.007.

Given that only few hackers completed either the entire battery or just some probes, a possible role of the hacking expertise or of the self-report hacking skills was investigated in relation with the number of tasks completed. No patterns were found. Of the 16 hackers that completed the battery, 4 reported 1 hack, 3 reported 2 hacks, 1 reported 3 hacks, 3 reported 4 hacks, 2 reported 7 hacks, 2 reported 9 hacks and 1 reported 12 hacks. As regards the self-rating of hacking skills, among the 16 hackers that completed the whole battery, 5 reported 1, 3 reported 2, 6 reported 3, 1 reported 5.

6.4.5 Bivariate correlations

Spearman's correlations were run to look for pattern of relationship between the tasks. Correlations between self-report measures and cognitive tasks and between hacking tasks and cognitive tasks are reported below. After applying Bonferroni-Holm correction for multiple comparisons few correlations still remained significant and are highlighted in bold. The new minimum threshold level of significance was p=.002.

The self-rating of hacking skills correlated with the number of hacking tasks performed **(Rho=.706, p=.000),** with SQ **(Rho =.353, p=.000),** with the novel scale-r **(Rho =.172, p=.001)**, with Raven RT **(Rho =-.309, p=.001)** and with score in the hacking challenge **(Rho =.249, p=.001).** The number of hacking tasks performed had two significant negative correlations with MRT score (Rho=-.184, p<.05), with the recognition score (Rho =-.200, p<.05). Morality scale correlated with the self-rating of hacking skills (Rho=.196, p<.01) and with the SQ (Rho=.190, p<.01). Other than the level of hacking expertise and the number of hacks performed, SQ correlated with the **Novel scale-r (Rho =.492, p=.000),** and with the order score (Rho =.202, p<.05), but not with the other tasks. Other than with SQ and the level of hacking skills, the novel scale-r had significant positive correlations with the score on the order task (Rho =.199, p<.05) and with RT in the hacking challenge (Rho =.237, p<.05), that is higher scores on the scale corresponded to longer reaction times on the hacking challenge. The correlation between the two questionnaires and performance on the order task indicated that a high level of systemizing and strong problem solving skills are related with the ability to recognize which one of two visual stimuli was presented first in a series.

Correlations between measures of mental rotation, field independence and hacking tasks were found. Bonferroni-Holm correction was applied and the minimum level of significance was set at p=.002 (N=24). The correlations in bold reported below are those who remained significant after the correction was applied.

- score on the hidden words search task had significant correlations with MRT score **(Rho =.356, p=.000),** Raven score (Rho =.214, p<.05) and RT (Rho =-.229, p<.05), recognition task RT **(Rho =.321, p=.001),** order task score **(Rho =.413, p=.000**), order task RT **(Rho =.285, p=.002),** GEFT score **(Rho=.372, p=.000)** and RT **(Rho =-.460, p=.000).** RT on the hidden words search task correlated with Raven rts (Rho =.243, p<.01), GEFT RT (Rho =.202, p<.05) and with RT in the recognition task (Rho =-.196, p<.05). This meant that the ability to find hidden words in a complex picture had a relationship either with the ability to mentally rotate 3D objects in a visual space, and with a cognitive style that is characterised by the ability to separate details from the surrounding context. It also had a relationship with a visual working memory tasks that required to remember if a stimuli was presented in a series, and also which one of two stimuli was presented first.

- Score on the hacking challenge had positive significant correlations with MRT score (Rho =.275, p<.01), recognition task RT **(Rho =.326, p=.002);** it had negative correlations with Raven RT **(Rho =-.488, p=.000)** and GEFT RT **(Rho =-.513, p=.000**). The RT on the hacking challenge correlated positively with GEFT RT (Rho =.221, p<.05). Results indicated that the ability to find a rule according to which a particular hint had to be transformed to reach the following level had correlated with the tendency to have a detail-focused cognitive style and with the ability to remember if a visual stimuli was presented or not in a series.

As in this study no gender differences were found in any cognitive task, I re-analysed all the correlation considering only the male sample, in order to investigate any change in the pattern of relationships between tasks. When considering only the male sample, the following correlations were found; correlations still significant after having applied Bonferroni-Holm correction are highlighted in bold.

The self-rating of hacking skills correlated only with the number of hacking tasks performed (**Rho =.652, p=.000**); and both correlated with the SQ (respectively Rho =.234, p<.01 and Rho =.169, p<.05). The number of hacking tasks correlated also with the recognition task score (Rho =-.307, p<.05).

The morality scale correlated with the self-rating of hacking skills (Rho=.213, p<.05) and with the novel scale-r (Rho=.206, p<.05).

SQ correlated with novel scale-r (**Rho =.511, p=.000**) and with the MRT score (Rho =.290, p<.05); while the novel scale-r correlated with rts in the recognition task (Rho =.261, p<.05) and with GEFT RT (Rho =.368, p<.01). This indicated a relationship between problem solving abilities and field independence; it also indicated that those with higher problem solving skills were slower in deciding whether a shape was presented or not in a series.

- Score on the hidden words search task correlated with order task score (Rho =.372, p<.01), with the GEFT score (Rho =.313, p<.01) and RT (Rho =-.371, p<.01). RT on the hidden words search task correlated with RT in the recognition task (Rho =-.323, p<.01), with GEFT score (Rho =-.301, p<.05) and RT (Rho =.305, p<.05) and with the hacking challenge score (Rho =-.302, p<.05). These findings supported a relationship between field independence and visual working memory and the ability to find hidden words in a picture. Contrary to what found in the analysis with the total sample, no correlations were found with the MRT task.

- Score on the hacking challenge correlated with MRT score (Rho =.358, p<.05) and with RT on the Raven task (**Rho =-.508, p=.000**) and on the GEFT task (**Rho =-.436, p=.002**).

Correlations with only the hackers sample were also investigated and Bonferroni-Holm correction was applied, so in bold are results which were significant after lowering the threshold level of p to .002.

The self-rating of hacking skills correlated only with the number of hacking tasks performed (Rho =.330, p<.01) and with the novel scale-r (Rho =.264, p<.01). The only significant correlation for the questionnaires was between them (**Rho =.446, p=000**). Novel scale-r also correlated with GEFT RT (Rho =.572, p<.01 As for the hidden words search task, the only significant correlation was between RT and Raven score (Rho =.480, p<.05). The only other significant correlation was between hacking challenge RT and the GEFT score (Rho =-.489, p<.05).

Given the substantial similarity between Study 2 and Study 3, datasets from the two studies were combined to analyse correlations and regressions.

6.4.6 Analyses on the combined datasets from Study 2 and Study 3

6.4.6.1 **Correlations**

Spearman's correlations were analysed to investigate significant relationships between the different variables examined. As before, in bold are reported the values that were still significant after having applied the Bonferroni-Holm correction. (new threshold value of p=.002).

Hacking challenge score correlated with rating of hacking skills (Rho=.175, p<.05), with MRT score (Rho =.164, p<.05), Raven rts (Rho=-.232, p<.01), serial recognition rts (Rho=.175, p<.01) and GEFT rts (Rho=-298, p<.01). Hacking challenge rts correlated with MRT score (Rho=-.152, p<.05), GEFT score (Rho=-.150, p<.05) and GEFT rts (Rho=.199, p<.01).

Hidden word search task correlated with rating of hacking skills (Rho=-.159, p<.05), moral scale (Rho=-.158, p<.05), MRT rts (Rho=.183, p<.01). Hidden words search rts correlated with MRT rts **(Rho=.239, p=.000)**, Raven rts **(Rho=.255, p=.000)**, GEFT rts (Rho=.223, p<.01).

As for the SQ score, it correlated with number of hacking tasks **(Rho=.239, p=.000)**, the rating of hacking skills **(Rho=.324, p=.000)**, novel scale-r **(Rho=.411, p=.000)** and the moral scale (Rho=.086, p<.01).

The novel scale-r correlated with the rating of hacking skills **(Rho=.117, p=.000)**, MRT rts (Rho=.123, p<.05), serial recognition rts (Rho=.148, p<.05) and order recognition score (Rho=.142, p<.05).

6.4.6.2 **Regressions**

Stepwise regression analyses were performed on the total dataset combined from Study 2 and Study 3 to investigate the predictive value of the cognitive measures and of the questionnaire for a) hacking challenge, b) hidden words search, and c) steganography performance (as measured by correct responses). Hacking challenge score and hidden words search score were considered dependent variables. Predictors were: SQ, novel scale-r, morality scale, MRT score and RT, GEFT score and RT, recognition score and RT, order score and RT, GEFT score and RT, global bias and local bias.

a) Dependent: hacking challenge score

A backward regression analysis was run to predict hacking challenge score from SQ, novel scale-r, morality scale, MRT score and RT, GEFT score and RT, recognition score and RT, order score and RT, GEFT score and RT, global bias, local bias.

Collinearity was not a concern as no VIF value was above 10 and no tolerance values were below .1 or .2. Independent errors assumption was met as the Durbin-Wason statistic was close to 2 (1.851). Histogram and normal P-P plot of the standardised residuals indicated that the distribution of errors approximated to a normal one.

Twelve models were extracted with the backward regression, all of which were statistically significant as shown in Anova table 6.10.
The best model had novel scale-r, MRT score and rts, Raven rts as predictors and had the following fit statistics: $F(4,97)=10.145$, $p=.000$, $R=.543$, $R^2=.295$, $\Delta R^2=.266$. This means that almost the 30% of the variance can be accounted for by the model.
The backwards regression model coefficients are reported in table F1, appendix F.

Table 6.10 Anova models of the backward regression analysis for hacking challenge score

Table 6.10

Anova models of the backward regression analysis for hacking challenge score

		Df	SS	MS	F	P
Model 1 (Constant), SQ score, Novel scale-r, Moral scale, MRT score, MRT rts, Raven score, Raven rts, Serial recognition score, Serial recognition rts, Order recognition score, Order recognition rts, GEFT score, GEFT rts, Global bias, Local bias	Regression	15	286.751	19.117	3.286	.000
	Residuals	86	500.268	5.817		
	Total	101	787.020			
Model 2 (Constant), SQ score, Novel scale-r, Moral scale, MRT score, MRT rts, Raven score, Raven rts, Serial recognition score, Serial recognition rts, Order recognition score, Order recognition rts, GEFT rts, Global bias, Local bias	Regression	14	286.745	20.482	3.562	.000
	Residuals	87	500.274	5.750		
	Total	101	787.020			

Model 3 (Constant), SQ score, Novel scale-r, Moral scale, MRT score, MRT rts, Raven rts, Serial recognition score, Serial recognition rts, Order recognition score, Order recognition rts, GEFT rts, Global bias, Local bias	Regression	13	286.576	22.044	4.243	.000
	Residuals	88	500.444	5.625		
	Total	101	787.020			
Model 4 (Constant), SQ score, Novel scale-r, Moral scale, MRT score, MRT rts, Raven rts, Serial recognition score, Serial recognition rts, Order recognition score, GEFT rts, Global bias, Local bias	Regression	12	286.391	23.866	4.639	.000
	Residuals	89	500.629	5.625		
	Total	101	787.020			
Model 5 (Constant), SQ score, Novel scale-r, Moral scale, MRT score, MRT rts, Raven rts, Serial recognition score, Serial recognition rts, GEFT rts, Global bias, Local bias	Regression	11	284.788	25.890	4.639	.000
	Residuals	90	502.629	5.580		
	Total	101	787.020			
Model 6 (Constant), SQ score, Novel scale-r, Moral scale, MRT score, MRT rts, Raven rts, Serial recognition score, Serial recognition rts, GEFT rts, Local bias	Regression	10	282.211	28.221	5.087	.000
	Residuals	91	504.809	5.547		
	Total	101	787.020			
Model 7 (Constant), SQ score, Novel scale-r, Moral scale, MRT score, MRT rts, Raven rts, Serial recognition rts, GEFT rts, Local bias	Regression	9	279.112	31.012	5.617	.000
	Residuals	92	507.908	5.521		
	Total	101	787.020			
Model 8 (Constant), SQ score, Novel scale-r, Moral scale, MRT score, MRT rts, Raven rts, Serial recognition rts, GEFT rts	Regression	8	274.653	34.332	6.232	.000
	Residuals	93	512.367	5.509		
	Total	101	787.020			
Model 9 (Constant), SQ score, Novel scale-r, Moral scale, MRT score, MRT rts, Raven rts, Serial recognition rts	Regression	7	267.144	38.163	6.900	.000
	Residuals	94	519.876	5.531		
	Total	101	787.020			
Model 10 (Constant), SQ score, Novel scale-r, MRT score, MRT rts, Raven rts, Serial recognition rts	Regression	6	260.618	43.436	7.839	.000
	Residuals	95	526.401	5.541		
	Total	101	787.020			
Model 11 (Constant), Novel scale-r, MRT score, MRT rts, Raven rts, Serial recognition rts	Regression	5	245.894	49.179	8.725	.000
	Residuals	96	541.125	5.637		
	Total	101	787.020			
Model 12 (Constant), Novel scale-r, MRT score, MRT rts, Raven rts	Regression	4	232.143	58.036	10.145	.000
	Residuals	97	554.877	5.720		
	Total	101	787.020			

b) Dependent: words search

A stepwise backward regression analysis was run to investigate the contribution of the predictors. All independent variables were inserted in the analysis: SQ, novel scale-r, morality scale, MRT score and RT, GEFT score and RT, recognition score and RT, order score and RT, GEFT score and RT, global bias, local bias. Coefficients of the stepwise regression model are reported in table F2 in Appendix F.

There was no collinearity between data and no outliers (St. Residual Min=-1.969, St. Residual max=1.960). Independent errors assumption was met (Durbin-Wason =.659). Histogram and normal P-P plots of the standardised residuals indicated that the distribution of errors approximated to a normal one.

The best model – model 12 - had GEFT rts, Global bias, MRT rts and MRT score as predictors. The fit statistics of the best model are: F(4, 116) 4.915, p=.001, R=.381, R^2=.145, ΔR^2=.115. This means that only 14% in the outcome can be accounted for by the predictors, which is quite low. Statistics for all models are provided in table 6.11.

Table 6.11 Anova models of the backward regression analysis for word search task

Table 6.11

Anova models of the backward regression analysis for word search task

		Df	SS	MS	F	P
Model 1 (Constant), SQ score, Novel scale-r, Moral scale, MRT score, MRT rts, Raven score, Raven rts, Serial recognition score, Serial recognition rts, Order recognition score, Order recognition rts, GEFT score, GEFT rts, Global bias, Local bias	Regression	15	226.514	15.101	1.674	.067
	Residuals	105	947.321	9.022		
	Total	120	1173.835			
Model 2 (Constant), SQ score, Novel scale-r, Moral scale, MRT score, MRT rts, Raven score, Serial recognition score, Serial recognition rts, Order recognition score, Order recognition rts, GEFT score, GEFT rts, Global bias, Local bias	Regression	14.	226.508	16.179	1.810	.046
	Residuals	106	947.327	8.937		
	Total	120	1173.835			
Model 3 (Constant), SQ score, Moral scale, MRT score, MRT rts, Raven score, Serial recognition score, Serial recognition rts, Order recognition score, Order recognition rts, GEFT score, GEFT rts, Global bias, Local bias	Regression	13	226.486	17.422	1.968	.030
	Residuals	107	947.349	8.854		
	Total	120	1173.835			

Model 4 (Constant), SQ score, novel scale-r, MRT score, MRT rts, Serial recognition score, Serial recognition rts, Order recognition score, Order recognition rts, GEFT score, GEFT rts, Global bias, Local bias	Regression	12	226.175	18.848	2.148	.019
	Residuals	108	947.660	8.775		
	Total	120	1173.835			
Model 5 (Constant), SQ score, novel scale-r, MRT score, MRT rts, Serial recognition score, Order recognition score, Order recognition rts, GEFT score, GEFT rts, Global bias, Local bias	Regression	11	225.256	20.478	2.353	.012
	Residuals	109	948.579	8.703		
	Total	120	1173.835			
Model 6 (Constant), SQ score, novel scale-r, MRT score, MRT rts, Serial recognition score, Order recognition score, GEFT score, GEFT rts, Global bias, Local bias	Regression	10	223.758	22.376	2.591	.007
	Residuals	110	950.077	8.637		
	Total	120	1173.835			
Model 7 (Constant), SQ score, novel scale-r, MRT score, MRT rts, Order recognition score, GEFT score, GEFT rts, Global bias, Local bias	Regression	9	219.341	24.371	2.834	.005
	Residuals	111	954.493	8.599		
	Total	120	1173.835			
Model 8 (Constant), SQ score, MRT score, MRT rts, Order recognition score, GEFT score, GEFT rts, Global bias, Local bias	Regression	8	215.743	26.968	3.153	.003
	Residuals	112	958.092	8.554		
	Total	120	1173.835			
Model 9 (Constant), SQ score, MRT score, MRT rts, GEFT score, GEFT rts, Global bias, Local bias	Regression	7	210.089	30.013	3.519	.002
	Residuals	113	963.746	8.529		
	Total	120	1173.835			
Model 10 (Constant), MRT score, MRT rts, GEFT score, GEFT rts, Global bias, Local bias	Regression	6	202.532	33.755	3.962	.001
	Residuals	114	971.302	8.520		
	Total	120	1173.835			
Model 11 (Constant), MRT score, MRT rts, GEFT rts, Global bias, Local bias	Regression	5	189.783	37.957	4.436	.001
	Residuals	115	984.051	8.557		
	Total	120	1173.835			
Model 12 MRT score, MRT rts, GEFT rts, Global bias	Regression	4	170.106	42.526	4.915	.001
	Residuals	116	1003.729	8.653		
	Total	120	1173.835			

c). Dependent: steganography score

For the steganography score only data from Study 2 were available. 15 models were extracted and the best model had SQ as predictor for performance on steganography task. The best model had the following fit statistics: $F(1,23)=10.506$, $p=.000$, $R=.560$, $R^2=.314$, $\Delta R^2=.284$. The score on the SQ was able to account for almost 30% of the variability in the outcome of the steganography task.

Table 6.12 anova stegano

Table 6.12

Anova models of the backward regression analysis for steganography task

		Df	SS	MS	F	P
Model 1 (Constant), SQ score, Novel scale-r, Moral scale, MRT score, MRT rts, Raven score, Raven rts, Serial recognition score, Serial recognition rts, Order recognition score, Order recognition rts, GEFT score, GEFT rts, Global bias, Local bias	Regression	15	70.934	4.729	2.005	.147
	Residuals	9	21.226	2.358		
	Total	24	92.160			
Model 2 (Constant), SQ score, Novel scale-r, Moral scale, MRT score, MRT rts, Raven score, Raven rts, Serial recognition score, Serial recognition rts, Order recognition score, Order recognition rts, GEFT score, GEFT rts, Global bias	Regression	14	70.806	5.058	2.368	.087
	Residuals	10	21.354	2.135		
	Total	24	92.160			
Model 3 (Constant), SQ score, Novel scale-r, MRT score, MRT rts, Raven score, Raven rts, Serial recognition score, Serial recognition rts, Order recognition score, Order recognition rts, GEFT score, GEFT rts, Global bias	Regression	13	70.769	5.444	2.799	.048
	Residuals	11	21.391	1.945		
	Total	24	92.160			
Model 4 (Constant), SQ score, Novel scale-r, MRT score, MRT rts, Raven score, Raven rts, Serial recognition score, Serial recognition rts, Order recognition score, GEFT score, GEFT rts, Global bias	Regression	12	70.721	5.893	3.299	.024
	Residuals	12	21.439	1.787		
	Total	24	92.160			
Model 5	Regression	11	70.324	6.393	3.806	.013
(Constant), SQ score, Novel scale-r, MRT score, MRT rts, Raven score, Raven rts, Serial recognition score, Serial recognition rts, Order recognition score, GEFT rts, Global bias	Residuals	13	21.836	1.680		
	Total	24	92.160			
Model 6 (Constant), SQ score, MRT score, MRT rts, Raven score, Raven rts, Serial recognition score, Serial recognition rts, Order recognition score, GEFT rts, Global bias	Regression	10	68.134	6.813	3.970	.010
	Residuals	14	24.026	1.716		
	Total	24	92.160			
Model 7	Regression	9	63.733	7.081	3.737	.012

(Constant), SQ score, MRT score, MRT rts, Raven score, Raven rts, Serial recognition score, Serial recognition rts, Order recognition score, Global bias	Residuals	15	28.427	1.895		
	Total	24	92.160			
Model 8 (Constant), SQ score, MRT rts, Raven score, Raven rts, Serial recognition score, Serial recognition rts, Order recognition score, Global bias	Regression	8	59.107	7.388	3.576	.014
	Residuals	16	33.053	2.066		
	Total	24	92.160			
Model 9 (Constant), SQ score, MRT rts, Raven score, Serial recognition score, Serial recognition rts, Order recognition score, Global bias	Regression	7	57.070	8.153	3.950	.010
	Residuals	17	35.090	2.064		
	Total	24	92.160			
Mod*e*l 10 (Constant), SQ score, MRT rts, Raven score, Serial recognition rts, Order recognition score, Global bias	Regression	6	53.435	8.739	3.960	.011
	Residuals	18	39.725	2.207		
	Total	24	92.160			
Model 11 (Constant), SQ score, MRT rts, Raven score, Order recognition score, Global bias	Regression	5	46.612	9.322	3.889	.014
	Residuals	19	45.548	2.397		
	Total	24	92.160			
Model 12 (Constant), SQ score, MRT rts, Raven score, Global bias	Regression	4	41.395	10.349	4.077	.014
	Residuals	20	50.765	2.538		
	Total	24	92.160			
Model 13 (Constant), SQ score, Raven score, Global bias	Regression	3	35.938	11.979	4.475	0.14
	Residuals	21	56.222	2.677		
	Total	24	92.160			
Model 14 (Constant), SQ score, Raven score	Regression	2	32.842	16.421	6.090	.008
	Residuals	22	59.318	2.696		
	Total	24	92.160			
Model 15 (Constant), SQ score	Regression	1	28.897	28.897	10.506	.004
	Residuals	23	63.263	2.751		
	Total	24	92.160			

All regression coefficients for steganography task are reported in Appendix F.

6.5 Comparisons between study 2 and 3 and discussion

Given the substantial similarity of the two studies, in this paragraph results found in each study are compared and similarities are discussed briefly, as findings will be extensively examined in the discussion chapter. First, the analysis on the novel scale-r revealed a different components' structure in the two studies.

Table 6.13 Components' structure of the novel scale-r in Study 1

Table 6.13
Components' structure of the novel scale-r in Study 1

	COMPONENTS	Loadings
1		
	8. * I do not feel comfortable with taking new perspectives into things (e.g. change my point of view, find alternatives…).	.717
	9. *When I find a way to solve a situation I do not feel the curiosity to find another way to solve it.	.689
	4. *I do not like learning new things (e.g. at work and in my spare time).	.634
	6. *When I encounter a problem, I do not usually look at it from different perspectives in order to come up with the best solution.	.606
	3. *I would not define myself as a person who thinks out of the box.	
2		
	5. I believe that no matter what life throws at me, I will be able to handle it.	.800
	7. I am good at finding solutions to problems that other would not be able to solve.	.737
	2. I think it is necessary to find always new and better solutions to a problem, even if the one I have used in the past was successful.	.584
	1. I like trying new things (e.g. hobbies, activities).	.412

Table 6.14 Components' structure of the novel scale-r in Study 2

Table 6.14
Components' structure of the novel scale-r in Study 2

	COMPONENTS	Loadings
1		
	9. *When I find a way to solve a situation I do not feel the curiosity to find another way to solve it.	.738
	7. I am good at finding solutions to problems that other would not be able to solve.	.726
	3. *I would not define myself as a person who thinks out of the box.	.650
	2. I think it is necessary to find always new and better solutions to a problem, even if the one I have used in the past was successful.	.647
	5. I believe that no matter what life throws at me, I will be able to handle it.	.353
2		
	1. I like trying new things (e.g. hobbies, activities).	.845
	8. *I do not feel comfortable with taking new perspectives into things (e.g. change my point of view, find alternatives…).	.731
	4. * I do not like learning new things (e.g. at work and in my spare time).	.691
	6. * When I encounter a problem, I do not usually look at it from different perspectives in order to come up with the best solution.	.442

The pattern of items distribution is different in the two studies, and when analysing only the male sample, or only the hackers sample items loaded differently in the two components as well. For this reason, the scale might be better considered as a one factor scale, given also the large variance of the items shared by two components. Importantly, all the analyses revealed that the construct measured by the novel scale-r is separate from the latent dimensions assessed by the SQ (and the SQ-R).

The similarity between Study 2 and Study 3 allows to perform analyses on the combined data from the two studies. Principal Component Analyses were then conducted on the novel scale-r alone and on the items of the novel scale-r and the SQ (see appendix 8 for fuller detail). When analysing the novel scale-r and the SQ together, results showed that items of the novel scale-r loaded on different components than the items of the SQ. Specifically, items 9, 3, 8, 7, 6 loaded on to component 2 and assessed problem solving abilities; while items 1,2,4,5 loaded on to component 9 and assessed resourcefulness/curiosity.

Gender differences were found on the SQ in Study 2 and Study 3, confirming that in males the drive to systemize is stronger than in females. No gender differences were found in the novel scale-r or on the morality scale; the first result is consistent with Study 2 but the lack of gender effect on the morality scale in inconsistent with the differences found in Study 2.

No gender differences were found on cognitive tasks, even when considering only the non-hackers sample; this means that superior males performance on MRT, GEFT and the hacking challenge found in Study 2 was not here replicated.

Results from the indicated that hackers have higher scored on the SQ compared with non-hackers, and this is consistent with what found in Study 1; they also have higher scores on the morality scale, indicating a lower level of morality as assessed by the four items than the non-hackers. Three of the four factors provided by Ling et al. (2009) were able to discriminate between hackers and non-hackers : technicity, structure, and topography. The novel scale showed no differences between hackers and non-hackers.

Findings indicated also that hackers had better performance on mental rotation, on the recognition task and they experienced less the local bias, i.e. the effect of local distractors. The finding of a superior performance on the mental rotation task which was not mediated by gender effect supported the idea that the cognitive ability might be involved on hacking expertise. The fact that hackers had a better performance on the recognition task, together with the correlation between the task and number of hacks performed, and hacking tasks supported a role of the recognition ability of the visual working memory on hacking performance. The superior ability showed by hackers to resist local distractors, and their higher scores on the SQ is consistent with the finding from study 2 that SQ was correlated with the same ability. Correlations between the novel scale-r and the SQ were confirmed in both studies, as it was the relationship between self-reported rating of hacking skills, number of hacking tasks and systemizing. Also the correlation between the morality scale and the self-reported rating of hacking skills was confirmed in study 2 and study 3.

Similarity and differences in the results are summarized in tables and discussed in the following lines.

Table 6.15 Comparisons between correlations of study 2 and study 3 for self-report measures.

Table 6.15
Comparisons between correlations of study 2 and study 3 for self-report measures.

	STUDY 2	STUDY 3	COMBINED DATASET
self-report rating of hacking skills	**SQ (Rho=.277, p=.000)** **novel scale-r (Rho =.106, p=<.05)** steganography score (Rho =.231, p=.000) **Hacking challenge rts (Rho =-.175,p<.05).**	**SQ (Rho =.353, p=.000)** **novel scale-r (Rho =.172, p=.001)** Raven rts (Rho =-.309, p=.001) **hacking challenge score (Rho =.249, p<.05)** Morality scale (Rho=.196, p<.01)	SQ (Rho=.324, p=.000) Novel scale-r (Rho=.117,p=000) Moral scale (Rho=.176, p=.000) Raven rts (Rho=-.200, p<.01) GEFT rts (-.136, p,.05) Hacking challenge score (Rho=.174,p<.05)
number of hacking activities performed	**MRT score (Rho= .297, p=.000)** Raven score (r=.190, p=.015), **Serial recognition score (Rho=.194, p=.023)** steganography score (Rho=.235, p=.002) hacking challenge rts (Rho =-.260, p=.003) Morality scale (Rho=.176, p=.007)	**MRT score (Rho =-.184, p=.05)** **Serial recognition score (Rho =-.200, p=.28)**	SQ score (Rho=.293,p=.000), moral scale (Rho=.188,p=.000)
SQ	**Novel scale-r (Rho =.359,**	**Novel scale-r (Rho =.492,**	Novel scale

	p=.000) steganography score (Rho =.194, p=.011) Local bias (Rho =-.210, p=.025)	**p=.000)** Morality scale (Rho=.190, p=.009) order score (Rho =.202, p=.026)	(Rho=.411,p=.000), moral scale (Rho=.088,p<.05)
Novel scale-r	Local bias (Rho =-213, p=.023)	order score(Rho =.199, p=.031) hacking challenge rts (Rho =.237, p=.027)	MRT rts (Rho=.123,p<.05), serial recognition rts (Rho=.148,p<.05)

Self-reported levels of hacking skills correlated with SQ, with the novel scale-r and with hacking challenge performance in both studies. This indicate that individuals with a strong drive to systemize and with high problem solving skills are those who reported higher levels of hacking skills; moreover, this self-report is directly related with performance in the hacking challenge, giving objective support to the subjective rating. The number of activities performed correlated in both studies with performance on MRT, but the relationship was positive in study 2 and negative in study 3. Results are conflicting because in the first study the finding was that the higher the number of hacks performed, the better was the ability to mentally rotate a 3D object in a visual space, while in the second one the more hacks performed the worse was the mental rotation ability. The same was true also for the recognition task, i.e. the task that required to remember whether a shape was presented or not in a series.

Analyses performed on the combined dataset from the two studies confirmed the correlation between self-report rating of hacking skills and the SQ and the novel scale-r. Moreover, the higher the self-report rating of hacking skills, the better was performance on the hacking challenge, as found in the two studies analysed separately. In the combined analysis, the self-report rating had a significant negative correlation with the GEFT rts, indicating that those who were faster on the GEFT were those who reported higher levels of hacking skills. The number of hacking activities performed correlated with score on the SQ and on the moral scale indicating that those who performed more hacks reported also higher levels of systemizing traits and lower levels of morality. In the combined analysis, a different pattern of correlations was found for the novel scale compared with the analyses performed on each study. In fact, in Study 2 the novel scale-r correlated with local bias, in Study 3 it correlated with the order recognition score and the hacking challenge rts while in the combined analysis the novel scale correlated with MRT rts and serial recognition rts. This indicated that higher scores on the novel scale-r were related with slower performance both on Mental Rotation test and on the serial recognition part of the visual working memory task. This could indicate that participants with higher levels of problem solving abilities took longer to solve these two tasks in the battery.

Table 6.16 Comparisons between correlations of study 2 and study 3 for hacking tasks.

Table 6.16
Comparisons between correlations of study 2 and study 3 for hacking tasks.

	STUDY 2	STUDY 3	COMBINED DATASET
Steganography score	Raven score (Rho =.190, p=.018) GEFT score (Rho =.191, p=.021)	Data not available	Data not available
Hacking challenge score	None	MRT score (Rho =.275, p=.010) Recognition rts (Rho =.326, p=.002) Raven rts (Rho =-.488, p=.000) GEFT rts (Rho =-.513, p=.000)	MRT score (Rho=.164, p<.05) Raven rts (Rho=-.232,p<.01) Serial recognition rts (Rho=.175,p<.05) GEFT rts (Rho=-.298,p=.000)
Hacking challenge rts	Raven score (Rho =-.250, p=.006) MRT score (Rho =-.182, p=.046) GEFT score (Rho =-.198, p=.037) **GEFT rts (Rho =.247, p=.009)**	**GEFT rts (Rho =.221, p=.039)**	MRT score (Rho=-.152,p<.05) GEFT score (Rho=-.150,p<.05) GEFT rts (Rho=.199,p<.01)
Crucipuzzle score / Hidden words search score		MRT score (Rho =.356, p=.000) Raven score (Rho =.214, p=.022) Raven rts (Rho =-.229, p=.014) Recognition rts (Rho =.321, p=.001) Order score (Rho =.413, p=.000) Order rts (Rho =.285, p=.002) GEFT score (Rho= .372, p=.000) GEFT rts (Rho =-.460, p=.000)	MRT rts (Rho=.183,p<.05)
Crucipuzzle rts / Hidden word search task rts	MRT rts (Rho =.311, p=.000) **Raven rts (Rho =.217, p=.012)** **GEFT rts (Rho =.213, p=.015)**	Recognition rts (Rho=-.196, p=.038) **Raven rts (Rho =.243, p=.009)** **GEFT rts (Rho =.202, p=034)**	MRT rts (Rho=.239,p=.000) Raven rts (Rho=.255,p=.000) GEFT rts (Rho=.223,p<.01)

In both studies a relationship between hacking tasks, field independence as measured by the GEFT and mental rotation as assessed with the MRT was found. Unfortunately, data from steganography task in steganography score could not be used because only two participants were able to find the encrypted message, but in study 2 the task correlated with performance on the GEFT.

The crucipuzzle task showed a correlation with MRT and GEFT, indicating that the ability to find meaningful words in a matrix of letters is related with the mental rotation ability in a visual space and with the tendency to focus on details. This is plausible as one individual to solve the task has either to mentally rotate letters because the words can be found in different axis within the matrix (i.e. horizontal, vertical, diagonal) and he or she has also to maintain the focus only on each single letter at a time, ignoring distractor letters all around.

Similarly, the hidden words search task related with MRT and GEFT too, and once again this is plausible because to find the words hidden in the picture one needs either to maintain a detail focused attention to ignore perceptual distractors and to mentally rotate the parts of the picture because words are hidden vertically, horizontally or in a curvilinear way. Moreover, in Study 3 a relationship with the hidden words search task and visual working memory was found. This correlation can be explained because one has to keep alive in the working memory space, specifically in the visuo-spatial sketchpad, the words already found and the parts of the picture already screened in order to complete the task on time and find all the words.

As for the hacking challenge, correlations with field independence and mental rotation were confirmed in both studies. This result is less explainable, especially for the involvement of mental rotation. One hypothesis is that the relationship is mediated by intelligence, as the relationship between MRT and measures of intelligence is demonstrated in the literature (Ling et al., 2009) and the two measures correlated well in the study. As for the correlation with field independence, it can be explained by taking into account the relationship between field dependence/independence and visual working memory. Research has in fact suggested that performance on tasks such as the GEFT primarily reflects the operations of the visuospatial and executive components of working memory (Miyake, Witzki & Emerson, 2001).

Analyses performed on the combined dataset from Study 2 and Study 3 confirmed the correlation between hacking expertise as measured by the hacking like tasks and performance on GEFT and on MRT. This gave support to the initial hypotheses regarding a role of field independence and the ability to mentally rotate objects in space on the ability to solve hacking tasks.

Hierarchic regression analyses were conducted with the combined dataset from Study 2 and Study 3 to investigate the role of the independent variables in predicting performances on hacking challenge and the hidden word search task. As for the hacking challenge the best model was formed by novel scale-r, MRT score and rts, Raven rts. For the hidden word search task the best model was formed by MRT score and rts, GEFT rts, global bias. In both cases the role of mental rotation in predicting the performance on hacking like tasks was confirmed. For the steganography task only data from Study 2 was available as no one in Study 3 was able to solve the task. The best predictor for the steganography performance was the score on the SQ. This is particularly interesting for this thesis as it gives support to one of the initial hypotheses which was that the drive to systemize could be a predictor of performance on hacking tasks.

The GEFT was a significant predictor only for the word search task but not for the hacking challenge. This can be explained by the fact that finding a word embedded in a more complex stimulus involves the role of the same cognitive skills as finding a simple shape embedded in a more complex figure. Vice versa, the role of the novel scale in predicting performance on the hacking challenge can be explained by the involvement of problem solving skills and curiosity in solving the logic challenges to pass the level in a successful way; and this is further supported by the role of fluid intelligence in predicting performance on hacking challenge.

So far results from each study were presented in different chapters. Chapter 4 described the first exploratory study on the distribution of systemizing traits in hackers and non-hackers, as well as the pilot testing of the novel scale. Chapter 5 described Study 2, a more complex experiment in which the initial hypotheses were tested within the general population. The aim was to investigate possible correlation between performance on certain psychological task and hacking expertise in the general population, measured with hacking-like tasks. The present chapter described Study 3 in which the same rationale of Study 2 was applied to a sample of hackers. Differently from Study 2, the Study 3 comprised also a capture the flag challenge (CTF) to assess hacking skills with proper hacking challenges that could be solved only by people with specific hacking expertise. Despite the initial aim, data from the CTF could not be used as those who completed the CTF did not volunteer to take part in my experiment, either the part with questionnaires and the psychological battery. For this reason, hacking expertise were operationalised as performance on hacking like task, as in Study 2. The following conclusive chapter will discuss more in depth results found in the studies comparing them with what is reported in the literature (presented in Chapter 2 and Chapter 3). Limitations of the present PhD will be discussed and possible future direction will be suggested.

7 GENERAL DISCUSSION

7.1 Introduction

In this chapter the main results of the three studies are discussed in light of previous findings reported in the literature. Individual differences in the distribution of systemizing traits across gender and hackers vs. non hackers are discussed, as well as differences on performance on cognitive tasks and hacking tasks. A possible account for explaining the main findings is given.

The present PhD is characterized by a degree of novelty. It benefits from an interdisciplinary approach between cognitive psychology and ethical hacking. The main aim was to develop a novel research approach on the topic of the cognitive skills that predispose to hacking expertise. The novelty of the research lies in the fact that this is the first effort to shed a light on a new field of research that can benefit from the combined contributions of cognitive psychology and ethical hacking. As discussed in the introduction, today cybersecurity is an issue of great concern as cyber-attacks are more frequent each year and the cost in terms of losses of money and data is increasing constantly. It is evident that the traditional approach based on antivirus and firewalls is not the best one as software that should protect the systems are not able to keep up to date with the most recent attacks. A new approach has been proposed which consists on hiring the so called ethical hackers, who are professionals specifically trained to think and perform like a hacker, but for the purpose to keep systems secure. That is, ethical hackers are hired by companies, industries and businesses to scan their systems, to try to violate them with the aim to find, reveal and fix bugs and holes in the systems themselves. To date, no research has been conducted on possible cognitive correlates of hacking expertise, so the approach of the thesis was an explorative one.

The empirical bases on which the present research rests belong to two different field of research: research on cognitive correlates of programming proficiency and research on the concept of systemizing.

Literature on programming was relevant to this thesis because programming it is a prerequisite of hacking; while the relevance of literature on systemizing was justified by the recent findings that hackers scored higher than the general population on

Systemizing Quotient questionnaire and on the attention to detail subscale of the Autistic Quotient questionnaire, which is a general feature of the ability to systemize. Studying the literature it was evident that some cognitive skills that were shown to correlate with programming proficiency were also shown to correlate with the concept of systemizing. A field independent cognitive style correlated with programming proficiency (Mancy & Reid, 2004) and there is evidence that systemizing abilities are correlated with the drive to attend to local details that characterise a field independent cognitive style (Billington et al., 2010). Mental rotation ability was related with better performance on programming (Cherney, 2008; Feng, Spence & Pratt, 207; Jones & Burnett, 2008) and was investigated in relation with systemizing with inconclusive results. In fact, Cook and Saucier (2010) did not find a correlation between MRT and the SQ, while Ling et al. (2009) found a significant correlation between the two measures.

Visual working memory tasks were shown to correlate with attention to detail (Richmond et al., 2013) and literature on programming highlights that visual working memory is important for programming proficiency (Carpenter et al., 1990).

After a thorough review of the literature, the following hypotheses were formulated to guide the studies.

- Hackers might have higher systemizing traits compared to the general population and this might result in higher scores on the SQ and on the SQ-R;
- Hackers might have strong problem solving abilities and resourcefulness traits and this might result in higher scores on a scale developed *ad hoc*;
- Systemizing might be related with hacking expertise;
- Field independence cognitive style might be related with hacking expertise by virtue of its relation with programming and systemizing ;
- Visuo-spatial abilities such as mental rotation ability and visual working memory ability might be related with hacking expertise by virtue of their relation with programming and systemizing;

An ancillary investigation regarded differences on morality traits between hackers and non-hackers, on the hypothesis that hackers might have higher manipulative traits than non-hackers. This hypothesis was based on the consideration that one of the most known hacking techniques is the so-called social engineering, which consists in manipulating others' people to obtain access to private information or data.

To investigate these hypotheses a battery of tasks was created that included self-report measures of systemizing and problem solving, cognitive measures of mental rotation, visual working memory, field independence and measures of hacking expertise. Three studies were conducted to investigate the hypotheses and findings were discussed in the chapter related to each study. Here the results will be drawn together to examine the overall findings and their implication within the framework of the Extreme male brain theory of autism and the related empathizing-systemizing theory of sex differences. Limitations of the studies and the generalizability of results are also discussed.

The novelty of the present thesis regards both the topic and the development of a novel scale. As for the topic, no prior investigation has been made on the cognitive skills that relate to hacking activities. Study 2 and 3 were designed specifically to conduct an investigation on the cognitive skills that can show a correlation with hacking expertise. A novel scale was ad hoc developed to assess two traits that, according to the literature, are characteristics of hackers – creativity and problem solving -. The process of creating the novel scale involved the creation of items, the pilot testing and the subsequent administration to a big sample of participants, both hackers and non-hackers. Additional data should be gathered before the validity of the novel scale could be confirmed or disconfirmed, and other analyses should be made to investigate the factor structure of the scale itself. Results from the studies conducted within the present PhD are inconclusive on this particular part. There are some insights that hackers might report higher scores than the general population, suggesting that they might possess stronger problem solving abilities and they might be more curious. These findings are not replicated in Study 2 and Study 3 as the novel scale did not show any correlation with measures of hacking expertise and moreover the scale was not able to discriminate between hackers and non-hackers, as in Study 1.

7.2 Overview of studies

Study 1 aimed at looking at distribution of systemizing traits and problem solving abilities between hackers and non-hackers. For this purpose, systemizing was assessed with the SQ while a novel scale was developed ad hoc to assess problem solving and resourcefulness/creativity among respondents.

Study 2 aimed at testing correlations between hacking skills, systemizing, field independence, and some cognitive abilities such as mental rotation and visual working memory in the general population. Individual differences according to gender and academic background were also investigated.

Study 3 aimed at investigating correlations between hacking skills, systemizing, field independence, and some cognitive abilities such as mental rotation and visual working memory in a sample of hackers compared with non-hackers. Individual differences on performances in such tasks between hackers and non-hackers were investigated.

The appropriateness of the tasks chosen to measure hacking skills was confirmed by the correlation between hacking challenge and steganography performance with the number of hacking activities performed, indicating that those who were involved in more hacks were those who performed better in the hacking challenge and in decrypting a hidden message. The lack of differences found between hackers and non-hackers on performance on the hacking tasks might be due in part to the fact that the number of hackers who completed the tasks was very small as compared to the number of non-hackers. Another possible account could be given by the fact that these tasks were not proper hacking tasks, as they were developed to asses hacking expertise in non-hackers rather than professional hackers.

7.3 General discussion of the results

Central to this thesis is the concept of systemizing, developed within the theoretical framework of the Empathising-Systemizing theory of sex differences (Baron-Cohen, Wheelwright, Griffin, Lawson & Hill, 2002), which was later expanded on to the Extreme Male Brain theory (Baron-Cohen, 2000; Baron-Cohen, 2002; Baron-Cohen & Hammer, 1997;). Systemizing is considered as the drive to analyse, construct and predict rule based systems; these latter can be of different kinds but they all share the same functioning based on rules. Among all systems, one of the best example are computer systems, who are almost 100% lawful and function on the basis of nothing but rules. According to the EMB account the strong attention to detail that characterize

ASC individuals is not just the outcome of a detailed focused cognitive style (as stated by the Weak Central Coherence account) but it is highly purposeful because it allows individuals to analyse the functioning of a system –i.e. systemize. This cognitive style drawn to local details does not presuppose that the individual would not understand the stimuli as a whole, as argued by the WCC, on the contrary, it is precisely thanks to this type of cognitive style that the individual can achieve an understanding of the whole stimuli by first analysing all its parts.

One of the main hypotheses of this thesis is built on the concept of systemizing as it was assumed to be possibly related to hacking expertise. Support to this hypothesis is provided by a recently established link between hacking and the positive traits of autism, as discussed in Chapter 3. Specifically, other than some renowned cases of hackers diagnosed with ASC reported by media, research have showed that hackers scored higher on the AQ, a questionnaire developed to assess autistic traits and that performance on tasks such as code breaking challenges was correlated with positive autistic traits such as an enhanced attention to details. Specifically, a new theoretical model of hacking was proposed: that systemizing might be related to hacking skills through attention to detail and the ability to analyse rules and patterns. The hypothesis was formulated according to two considerations. On one hand, the findings of a correlation between hacking and positive autistic traits. On the other hand the finding that certain tasks that are reported in literature as being related to programming proficiency have also been related to characteristic traits such as systemizing and attention to detail in the general population.

One might argue that also programmers might show the same enhanced systemizing ability as they typically develop computer systems that hackers then try to force and break. For this reason, differences between hackers and programmers on measures of systemizing traits were investigated.

7.3.1 Gender differences

Despite not being the central focus of this thesis, the EMB theory is the framework in which the concept of systemizing was first formulated, and so will be referred to as a useful framework to discuss results here presented.

All three studies confirmed that males show higher systemizing traits as measured by the SQ-R and the SQ compared with females and this is consistent with the findings reported elsewhere in the literature (Baron-Cohen et al., 2003; Billington, Baron-Cohen, & Wheelwright, 2007; Wheelwright et al., 2006) and scores in SQ were consistent among Study 2 and Study 3 supporting a cross-cultural validity of the instrument among Italian and English populations.

Overall findings are in accordance with the EMB which argues that the male cognitive profile is characterized by a strong drive to systemize as compared to the strong drive to empathise of the female brain.

Table 7.1 Comparison of SQ-R, SQ and novel scale-r scores between Study 1, Study 2 and Study 3.

Table 7.1
Comparison of SQ-R, SQ and novel scale-r scores between Study 1, Study 2 and Study 3.

		Study 1	**Study 2**	**Study 3**	**Study 1**	**Study 2**	**Study 3**
		SQ-R	**SQ**		**Novel scale-r**		
Males	Mean	64.74	36.95	37.91	10.34	10.14	10.18
	Sd	18.798	9.273	11.55	3.7	3.57	3.73
	Median	64	36	38	10.5	10	10
	N	89	151	160	89	151	160
Females	Mean	57.72	29.98	28.60	8.45	10.15	9.46
	Sd	20.149	9.12	12.459	3.5	3.45	3.99
	Median	54	30	28	9	10	10
	N	71	422	183	71	422	183
		U=2447, z=-2.45, p<.05, r=.19	U=19207, z=7.252,p=.000,r=.3	U=8192.5,z=-.7040,p=.000,r=.14			

Table 7.1 Scores on SQ-R and SQ reported in literature.

Table 7.2
Scores on SQ-R and SQ reported in literature.

		SQ-R			**SQ**		
		Billington et al., 2008	**Whakabayashi et al., 2006**	**Baron-Cohen et al., 2003 a**	**Ling et al., 2009 a**	**Ling et al., 2009 b**	**Ling et al., 2009 c**
Males	Mean	60.22	61.2	30.3	30.02	32.1	30.18
	Sd	25.65	19.2	11.5	8.6	10.39	10.22
	N	9	723	114	71	84	50

Females	Mean Sd N	56.55 30.57 11	51.7 19.2 1038	24.1 11.2 164	21.8 8.51 95	22.54 8.49 83	23.42 10.91 50
Mean differenc es		P=.710	F(3,1751)=83. 9, p<.0001	F(1,270)=18.1 ,p<.0001, d=.74	T(164)=6.1 3, p<.0005, d=.96	T(165)=6. 5, p<.0005, d=1.01	T(98)=3.2, p=.002,d=.6 5

Males scored higher than females on the morality scale in both Study 2 and Study 3, but the difference was significant only in Study 2. The gender difference is consistent with findings reported in the literature with the same instrument (Miller, Gaughan, & Pryor, 2008) suggesting that males have lower morality traits as compared to females.

The novel scale-r, administered as a self-report assessment of problem solving and resourcefulness ability showed inconsistent results. Males scored higher than females in Study 1 and Study 3 but not on Study 2; and the difference was significant only in Study 1. This indicates that overall males and females did not differ significantly in their level of problem solving ability or resourcefulness ability.

As for the cognitive tasks, accordingly to what reported in literature, an effect of gender was expected on field independence (Kagan & Kogan, 1970; Linn, & Petersen, 1958) and on spatial ability tasks as a large body of literature reports male superiority on such tasks (see Andreano & Cahill, 2009 for a review). On the Navon task results from studies investigating sex differences on performance are inconclusive as there is no consistency among findings (Pletzer, Petasis, & Cahill, 2014)

Gender differences were found in Study 2 (but not in Study 3) on cognitive measures. The lack of gender effect on Study 3 might be accounted for by the different samples of participants, or by the fact that the small sample size of Study 3 as compared to Study 2 failed to detect any effect.

On the overall sample the typical global precedence effect was found on the Navon task, as demonstrated by: faster RTs and more correct recognitions on the Global condition as compared to the local condition; slower RTs and fewer correct recognitions on the incongruent consistency as compared to the congruent one; and an effect of local bias when the local level of the stimuli interfered with the recognition at the Global level. No gender differences were found on the task, consistently with previous findings (Billington et al., 2008).

Males superiority in mental rotation abilities was found in Study 2, which is consistent with other reports in the literature (Halpern & Wright, 1996; Ling et al., 2009; Linn & Petersen, 1985; Mackintosh & Bennett, 2005; Voyer, Voyer & Bryden, 1995;). On the one hand this finding is concurrent with the established male superiority in spatial ability tasks and on the other hand it gives further support to the idea that males outperform females in tasks that tap systemizing ability. The mental rotation of 2D or 3D object involves systemizing as the rotation is guided by rules of transformation of the objects. However, this superiority was not found in Study 3 and this might be due for the above mentioned reasons.

Superior performance in males in a measure of field independence was found in Study 2, consistent with what reported in the literature (Jolliffe & Baron-Cohen, 1997) suggesting that males are more likely to have a field independent cognitive style than females. This is consistent with the EMB theory as field independence is linked to a detailed focused cognitive style, which is characterized by a strong focus to local details which in turn is what allows individual to systemize. However, results were not replicated in Study 3.

The other task in which males shown superior performance was the hacking challenge. This is consistent with the fact that males reported having performed more hacking activities and reported higher hacking skills compared to females.

Ancillary analyses were performed to compare different academic backgrounds in Study 2. Consistent with the literature, individuals with a science background scored higher on the SQ than those with a social science background. Results from Study 2 indicated that computer science scored even higher than science background but the difference was not statistically significant. Consistent with the literature (Wheelwright et al., 2006), individuals with a natural science background are stronger systemizers than those with a social science background, and a novel finding is that individuals from computer science degrees scored even higher than those from natural science.

Superior performance was found in the hacking challenge for individuals with a science background, indicating that they are more proficient in the inferential cognitive task.

7.3.2 Differences between hackers and non-hackers

Findings in both Study 1 and Study 3 indicated that hackers have a stronger drive to systemize than non-hackers. Significant differences were found on SQ factors which tap interests in topography, in technicity and in the structure of things. The DIY factor did not show any significant difference between group.

Interestingly compared to a group of programmers, hackers scores were still higher and the difference was significant. Analyses were made on the male sample only to avoid possible gender effect on the SQ. Specifically the different was on the topography and structure factors, but it was not significant after applying the correction for multiple comparisons.

Table 7.2 Comparison of SQ-R, SQ and novel scale-r scores between hackers and non-hackers in Study 1 and Study 3.

Table 7.3
Comparison of SQ-R, SQ and novel scale-r scores between hackers and non-hackers in Study 1 and Study 3.

		SQ –R	**SQ**	**Novel scale –r**	
		Study 1	**Study 3**	**Study 1**	**Study 3**
Hackers	Mean	65.44	39.82	10.36	10.28
	Sd	18.590	11.18	3.83	3.75
	Median	66	39	11	10.5
	N	64	104	64	104
Non hackers	Mean	59.08	30.17	8.92	9.62
	Sd	20.037	12.41	3.58	3.89
	Median	56.50	30	9	10
	N	96	245	96	245
Mean differences			U=6823,z=-6.451,p=.000,r=.35		T(336)=2.529,p=.012

This means that there is evidence that hackers do possess stronger systemizing traits than programmers.

Within the hackers group, male hackers scored lower on the SQ-R than male non-hackers, while female hackers scored higher than female non-hackers. Interestingly, female hackers scored even higher than male hackers, while female non hackers had the lowest scores among all the four groups.

As for the novel scale-r, even if in both Study 1 and Study 3 hackers scored higher than non-hackers, the difference was significant only in the first study. It might be that the failure to detect an effect was due to the online administration of Study 3 compared to Study 1, in which participants completed the questionnaire on paper and pen at the presence of the researcher. This type of administration might have induced participants to be biased by the social desirability and to provide more biased responses than the ones given on the online questionnaires. Another possible explanation was that in Study 1 all hackers tested were students from ethical hacking degree, while in Study 3 the hackers group comprised either students from an ethical hacking degree either professionals with a different background. To control for the possible effect of the academic degree, the same analyses were run in Study 3 only considering ethical hacking students, but the results for the novel scale were still not significant. This support the first hypotheses.

In Study 3 hackers were found to have lower morality traits as compared to non-hackers, and also to programmers, even when controlling for sex. This is consistent with the idea of hacker penetrating into computer systems and manipulating people to obtain restricted and confidential information through social engineering techniques. This finding support the hypothesis that hackers and programmers might possess different attitudes, as discussed in Chapter 2.

As for the cognitive measures, a superior performance was found on the mental rotation ability together with a less local bias as compared to non-hackers. This indicates that hackers performed better on task that requires to mentally rotate a 2D object in space and they are more able to resist the interference of distractors at a local level. This is consistent with the systemizing account, as the theory posits that the enhanced attention to detail that characterized individuals with high systemizing ability is purposeful to analyse and understand the system rather than being a biased cognitive style. This means that when instructed to attend the global level, individuals with high systemizing traits can inhibit their tendency to be drawn to local details. No other differences were found between hackers and non-hackers; and this might be due to the small sample size of participants who completed the tasks, as among hackers, less than 30 participants completed the cognitive tasks and only 16 hackers out of 104 completed the battery entirely.

7.3.3 Systemizing and Hacking skills

Other than the finding that hackers have higher scores on self-report measures of systemizing than non-hackers; the relationship between systemizing and hacking skills was further proved by correlation analyses. A relationship between hacking expertise and self-report measures of systemizing was confirmed by the correlation between SQ-R and time spent on hacking activities (Study 1), and by the correlation between SQ and either number of hacking activities performed and self-report rating of hacking skills (Study 2 and Study 3). This means that those who are on the higher end of the systemizing continuum are those who report of having engaged in more hacking activities and report being more confident about their hacking skills. Objective ground to this self-reported data is given by the fact that indeed both the number of hacks performed and the level of hacking expertise were related with superior performance in the steganography task and in the hacking challenge. According to results from Study 2, those who reported higher scores on the SQ were also those who performed better when asked to find a secret message embedded in the text. In other words, systemizing was found to be related with the ability to decrypt a message; supporting partially one of the initial hypothesis on the relationship between systemizing and hacking tasks. Steganography is a task that taps systemizing abilities as the encryption and decryption techniques are ultimately lawful and rule based. The message is hidden according to transformation rules that need to be discovered by ignoring the plain text, i.e. the message that embeds the secret information, and focusing on each letter to find out the rule according to which the information was hidden. Those who are strong systemizers are more likely to perform better in this type of tasks. In fact, regression analyses performed on the steganography task showed that the only significant predictor for this task was score on the SQ. This finding gave substantial support to one of the initial hypotheses on a role of systemizing ability in performance on hacking like tasks.

Contrary to the initial hypothesis, other two measures of hacking expertise – hacking challenge and the word search task did not correlate with systemizing but this result should be interpret with caution in light of the following considerations. The task that required to find hidden words in either a matrix of letters or a picture, taps less the domain of systemizing and more the attention to detail domain. Participants have to scan the visual stimuli and extract from the background letters that compose a meaningful word; so the cognitive processes involved are more attention to details, together with the ability to mentally rotate letters to create a word and the ability to disembed the letters from the distracting information on the background. There is no systemizing ability involved, as there are no rules to find in order to understand the functioning of the task. However, this finding is consistent with what previously reported by Harvey et al. (2016) who found that systemizing was not related with a tasks that required attention to detail, but was instead related with a code breaking challenge.

As for the hacking challenge, it consists of a hierarchical task that required participants to understand the rule according to which a given hint was presented, in order to type the correct answer to proceed to the following level. To solve the challenge, a participant had to first understand what actually the hint meant and how to transform it (i.e. if in the third level the hint was 333, then to reach the fourth level the correct answer was not 3333 but 4444). In its essence, the task should require a certain amount of systemizing to be solved, but findings did not support this hypothesis.

7.3.4 Hacking skills and cognitive measures

The initial hypothesis was that certain cognitive abilities and cognitive styles might be related with hacking skills on the basis of different considerations: a) literature showed that the same cognitive abilities are involved in programming proficiency; b) the same cognitive abilities are related with systemizing and c) there is reason to think that hacking expertise might involve systemizing ability. In this section, findings for each of the cognitive measures administered in the studies are discussed.

Field independence

All tasks measuring hacking expertise were related with field independence. The correlation between steganography task and GEFT suggested a role of field independence in the ability to decrypt and hidden message within a text. This means that individuals with the tendency to approach a stimulus analytically and with a detailed-focused cognitive style are better at deciphering an encrypted message. This finding is plausible because in order to find the secret message participants had to dissect the plain text and focus the attention on each letter that composed the message, without being distracted by the meaning of the message as a whole.

Performance on tasks that required to find hidden words in a matrix of letters (crucipuzzles) and in a picture (hidden words search tasks) was related with performance on the GEFT in both studies but the results from Study 2 and Study 3 were slightly different. In Study 2 the relationship was between reaction times, i.e. those who were faster at finding words in the matrix were also faster at disembedding the simple shape from the complex shape. In Study 3 the positive relationship between reaction times was confirmed, and was supported by a relationship also between scores. So those who were faster and found more words in the picture, were also those who were faster and found more simple shapes hidden in complex ones. The relationship between the tasks is plausibly explained by taking into account that both GEFT and the hacking tasks required to dissect the organized visual field, direct the attention towards parts of the stimuli and separate them from the overall picture. Regression analyses confirmed the role of performance on GEFT in predicting the outcome of the hidden words search task. Even if the significant predictor was reaction times on the GEFT and not the score, this result suggest an involvement of a field independent cognitive style in solving a task that require to find hidden words in a complex stimulus.

Field independence was involved also in the hacking challenge in both Study 2 and Study 3. Faster reaction times on the hacking challenge corresponded to better performance on the group embedded figure test. This relationship was further supported by the regression analysis which revealed that faster reaction times on GEFT was a significant predictor performance on the hacking challenge. The role of field independence in hacking challenge task is explainable by the fact that both task requires a local processing style in that to solve the challenge one had to focus the attention on small pieces of information, to retrieve them from memory avoiding the distractor effect of confounding information.

Moreover, field independence was demonstrated to represent an advantage on tasks such as problem solving (Nicolau & Xistouri, 2011); searching and information seeking (Gan & Bai, 2007) and tasks involving visuospatial memory and computer-based skills (Rittschof, 2010). The hacking challenge indeed required problem solving abilities, information seeking and it was *per se* computer based. In both the disembedding task and the hacking challenge, participants had to find the rule according to which a stimulus has to be changed in order to proceed to the following level.

Mental rotation

The relationship between mental rotation ability and hacking performance was supported by the results. Higher scores on the hacking challenge were related with higher scores on mental rotation ability. This finding can be explained by the fact that both tasks are based on rules of transformation that participants have to detect in order to provide the right answer. Both of them are in this sense tasks that tap the systemizing domain as they are rule-governed.

As for the hidden words search tasks, Study 2 and Study 3 confirmed a relationship with mental rotation abilities. Performance in these tasks require participants mentally rotate the letters (either in the matrix and in the picture) in different directions – vertical, horizontal, diagonal –to combine them together to create a meaningful word. Moreover, regression analyses showed a role of performance on MRT in predicting scores on both the hacking challenge and the hidden words search task. This meant that the ability to mentally rotate objects in space has a significant role as a predictor for hacking expertise, as assessed in studies that are part of this thesis.

Visual working memory

The relationship between visual working memory abilities and hacking tasks was supported only partially. In Study 3 performance on the hacking challenge correlated with faster performance on the recognition part of the working memory. The involvement of the visual recognition working memory in the hacking challenge is plausible, as the hacking challenge requires the activation of a certain amount of information in order to a) understand the semantic beyond the hint and b) apply inferential reasoning to provide a correct answer and c) retrieve from memory appropriate and useful information. The question is why only the serial recognition but not the order recognition part of the visual working memory task had correlation with the hacking challenge. The two parts of the visual working memory task differed slightly one from the other. In both of them participants were presented with a series of

4 abstract shapes, the different between the two parts was that a) in the recognition task there was one target stimulus and participants had to judge if it was part or not of the set of stimuli, while 2) in the order task there were two target stimuli and participants had to judge which one of the two was presented first. The first part involved just a visual-recognition while the second part involves the role of temporal order memory. It is likely that in the hacking challenge the process involved is just the recollection from memory (part of the recognition memory) of information or previously seen stimuli such as the ones presented in order to provide the correct answer.

In Study 3 correlations were found between words search task both the recognition and order part of the visual working memory task. In the hacking task, participants had to integrate different pieces of information; they had to recognize familiar words formed by the combination of letters and they had to remember where the words already found were and on the other hand, where were parts already scanned with no positive results.

7.3.5 Systemizing and cognitive measures

Correlations between SQ and the novel scale were present among all three studies suggesting that problem solving abilities are related with systemizing. Considering that the ability to systemize involve analysing a system, understanding its functioning to perform operations on it, it is possible that those who possess better problem solving skills are the ones who success in tasks that require the input-operation-output reasoning.

The negative correlation between SQ scores and the local but not global interference indicates an inverse relationship between systemizing traits and the effect of distractors at the local level. This means that individual who are strong systemizers are those less experienced to local bias while weak systemizers tend to suffer from the effects of local distractors. This goes in the opposite directions of what previously found by Billington et al., (2008), but in their study the sample size was very small (i.e. 26 participants) so other studies are needed to further investigate this relationship.

No correlations were found between SQ and mental rotation task. This finding is in line with what found by Cook and Saucier (2010) who did not found any correlation between SQ and MRT performance. Other authors (Ling et al., 2009) found a correlation between 18-item version of the SQ and MRT but this results is not here replicated as either the original SQ nor the 18 item version showed any significant correlations with the ability to mentally rotate objects in space. The relationship between these two cognitive skills needs to be further investigated, as MRT is considered to be a measure of systemizing abilities (Baron-Cohen, 2002) end more evidence is required to prove this relationship.

In Study 3 a correlation was found between SQ and the order part of the visual working memory; meaning that those with high systemizing traits performed better when asked to judge which one of two shapes were presented first in a set of stimuli. This findings might be explained by the fact that in order to judge which one of the two abstract figures came first, one has to pay attention to the small details that distinguish one figure from the other, as differently from the recognition part the two target stimuli are presented at the same time. Richmond et al. (2013) found a correlation between serial recognition part of the visual working memory task and the attention to detail subscale of the AQ. Findings from the present studies are not consistent with what found by Richmond et al. (2013). In fact the correlation that emerged in Study 3 was with the other task – i.e. the order recognition task – and not the serial recognition task. The correlation between attention to detail and the serial recognition task can be explained considering that participants had to see a series of four shapes and then judge whether one was present or not in the series. This involves attention to detail because it is necessary to pay attention to small details that distinguish one shape from the others. On the other hand, the task that requires to judge which one of two shapes were presented first involves the ability to systemize because in this case the task is further complicated by the need to choose which one was presented first. Attention to details is purposeful directed towards the understanding of the pattern of presentation of stimuli.

7.4 Limitations

The present study suffers from several limitations, in part due to its explorative nature, in part due to the type of administration which was an online one. One of the major limitations is certainly the lack of a proper hacking task to assess performance on hackers but this is not due to limitations of the study *per se.*

- *Lack of controlled setting*. Study 2 and Study 3 were administered online; this was motivated to the need to reach as many participants as possible and to be able to generalize results obtained to a large sample of population. Nevertheless, the limit of the online administration id s clearly the lack of a controlled setting, and the role of many confounding variables could not be controlled for. Even if participants were explicitly instructed to avoid distraction for the duration of the experiment, there was no way in which this could be ascertained. Even if this limitation was partially controlled with additional post hoc analyses on the raw data, it is still a bias of the study.

- *Validity of the hacking tasks*. Hacking expertise was measured with hacking-like tasks developed to mirror the most common hacking activities – i.e. steganography and injection -. At first, these tasks aimed at assessing hacking expertise in non-hackers, while the CTF challenge described in Chapter 6 was developed to measure performance on technical hacking tasks. Data from the CTF could not be used though because hackers who completed it did not volunteer to take part on the psychological battery. This is certainly a major limitation of the study, although it is not attributable to the research design in itself.

- *Sample size.* Despite the quite large amount of subjects who completed the first part of the studies, relatively a few of them volunteered to complete also the second part. Of those who left their email to receive the link for the battery of psychological tasks then, not all in fact did the test, and of those who started the battery, a small amount completed the sequence of tasks in its entirely. There was a high rate of withdraw between the first part and the second part. One way in which this could be avoided would be administering both parts in one session; but this would have increased the length of the experiment to almost one hour and the concern was that many participants would have aborted prematurely the battery.

- *Navon task.* The failure to detect a relationship between systemizing and/or hacking expertise and the Navon task might be due to the fact that in this version participants were explicitly instructed to attend either the global level or the local one, so a spontaneous tendency toward one level or another was not assessed.

- *Self report measures.* Systemizing was here assessed through self-report questionnaires, which does not represent an objective measure of performance. The problem with self-reports is that they rely on introspective ability of the participants and on the honesty of their responses; for these reasons such measures suffer from response bias which potentially can compromise results found.

- *Selection of tasks*. The selection of tasks that constituted the battery was in many senses an arbitrary one. It was guided by the review of the literature but given the explorative nature of the studies it was not supported by previous research on the specific topic of interest here, i.e. the cognitive correlates of hacking expertise.

- *Novel scale – r.* The novel scale developed to investigate problem solving and resourcefulness did not shown to be discriminative between hackers and non-hackers. This might be due to a lack of internal validity of the scale, as distributions of items on the two components were not consistent between the three studies. It might be also that the scale had face validity but poor content validity, that is it appeared to measure the problem solving construct but in fact it did not assess the construct.

- *Confounding variables*. The behavioural battery comprised tasks that were hypothesized to be correlated with hacking performance but it did not guarantee any control over the effects of confounding variables, i.e. the role of visual acuity in performance on the battery of task, as the majority of tasks involved a focused attention.

- *Statistical analyses*. One of the limitations of the present research is the kind of analyses performed. The data gathered did not follow a normal distribution according to results of the analyses performed, so non-parametric tests were used to analyse the data. The limitations of non-parametric analyses lie mainly in the fact that results cannot be generalized to the population from which the sample was taken.

7.5 Future directions

The present thesis investigated possible correlated of hacking skills at the behavioural level using and explorative approach as no prior research was made on the topic. Findings provide some preliminary insights on the possible involvement of cognitive abilities on performance on hacking tasks. Further investigation is needed to give support to the results found in this study and future studies might replicate or extend the present research overcoming its limitations.

Specifically future studies could:

- Increase the sample size of the hackers population. Assessing more participants could lead to more robust findings on the correlations between hacking expertise and other cognitive measures as well as on individual differences between hackers and non-hackers;
- Assessing hacking expertise with proper hacking tasks. Despite a proper CTF challenge was part of Study 3 it was not possible to correlate performance on such task with performance on cognitive measures. So future studies could assess hacking expertise with specific hacking tasks;
- Assessing systemizing traits not only with self-report measures but with behavioural tasks.
- Investigate the possible correlations between other cognitive abilities and hacking performance;
- Administering experiments in a more controlled setting to avoid the possible effect of confounding variables;

- Investigating the possible difference found between students from ethical hacking degrees and professional ethical hackers to assess the role of job experience on the possible correlations with cognitive measures;
- Extending the investigation of correlates of hacking on a neural level. It could be interesting investigating the involvement of specific brain regions on the performance of different hacking tasks;

Future studies should overcome the major limitations of the present study. It is recommended to use a control setting instead of an online administration; this will guarantee a control over the effect of distractors and assure that the focus of attention is maintained throughout the experiment. Other studies should ensure that hackers complete both the proper CTF challenges and the cognitive tasks; my efforts to persuade hackers to volunteer to complete the battery did not succeed so this is something that should be taken into great account in the future.
The novel scale needs additional testing to investigate its validity and reliability, not only with ethical hackers but also with the general population in order to have normative data to refer to.

7.6 Conclusions

The present thesis represents an explorative study on the cognitive skills that correlates with hacking expertise. A thorough review of the literature revealed that to date, no study was conducted on the topic. The initial hypotheses formulated were derived both from the literature on programming skills, on the assumption that both hackers and programmers share the same skills, and from the recent evidence that hackers do possess higher positive autistic traits such a strong attention to details. The main hypothesis formulated in this thesis was that the enhanced attention to detail shown by hackers might be purposeful to systemize, i.e. to analyse and understand computer systems.
This hypothesis was supported either by the finding that hackers have higher scores on systemizing as compared to non-hackers, and by the correlations found between self-report measures of systemizing and performance in a representative hacking task such

as steganography. Further support was given by the fact that the number of hacking activities performed as well as the ratings of hacking skills showed a positive relationship with self-reported systemizing traits.

Initial hypotheses on the role of certain cognitive skills on hacking expertise were also formulated and were partially supported by results. Specifically, mental rotation ability was related to hacking expertise, as predicted. Also a field independent cognitive style had a positive relation with performance on hacking tasks. They hypothesis of an involvement of visual working memory was also partially supported by the studies. Given that either mental rotation ability and field independence are constructs that have been related to systemizing, overall the findings taken together point to a peculiar role of the ability to systemize on hacking expertise. The initial theoretical framework proposed, according to which hackers have high systemizing abilities mediated by attention to details and the ability to analyse rules and patterns seems to be partially supported by the findings of the present thesis in light of the results found. The overall findings of this thesis have both theoretical and potential practical implications. On a theoretical point of view, this thesis offers some insights on the role of possible cognitive skills on hacking expertise, and thus contributes to fill an existing gap in the literature. On the practical point of view, results might have potential implications for the development of an evaluation toolset that might help the process of hiring candidates for ethical hacking positions. The recruitment of applicants is now based solely on interviews or on evaluations of performance on hacking challenges. An evaluation based on the assessment of cognitive skills that are demonstrated to be related with that specific job performance might add more objective values to the screening process. This latter is just a potential future implication of the results obtained in the present thesis. Further research is needed to either prove or disprove findings discussed here; but this might be the starting point for a new field of research. As further research is conducted and further results are found, the practical value of this field of research can become evident. That is, it might provide useful assessment instruments to evaluate the cognitive skills that relate with hacking expertise.

Appendices

Appendix A. Ethics approval for Study 1

JM/CW/CR/SHS/14/P/020

24th February 2015

Samuela Bolgan
101 Rosebank Street
Dundee
DD3 6PG

Dear Samuela

Individual Differences on Systemizing Quotient Questionnaire Scores

This is to notify you that the Ethics Committee have looked at your submission and you have been granted **full ethical approval** to collect data for your project as entitled above. This is subject to the following standard conditions:

i You must remain in regular contact with your project supervisor

ii Your supervisor must see a copy of all experimental materials and your procedure prior to commencing data collection

iii If you make any substantive changes to your project plan, you must submit a new ethical approval application to the Committee. Application forms and the accompanying explanatory document are on the Intranet. Completed forms should be resubmitted through the Research Ethics Blackboard course.

iv Any changes to the procedures must be negotiated with your supervisor

Failure to comply with these conditions will result in your ethical approval being revoked by the Ethics Committee.

The Committee observed that relevant ethical issues are covered as regards informed consent, questionnaire response confidentiality, and debrief sheet.

Should you have any queries please contact your Supervisor.

Yours sincerely

School Ethics Committee

School of Social & Health Sciences

Appendix B. Ethics approval for Study 2 and Study 3

Abertay University

Project Reference Number: SHS_T_2015-16_889
Project Title: **Individual differences in cognitive skills and hacking-related tasks**

Proposer: **Samuela Bolgan**
Matriculation number: 1405345
Programme: , Stage

Supervisor: Elena Rusconi

The above Project has been granted **Full ethical approval**.

Additional Conditions:

NB: you are not required to resubmit your application if you have been given Additional Conditions.

Standard Conditions:
These apply to all Research Ethics applications

i The Proposer must remain in regular contact with the project supervisor.

ii The Supervisor must see a copy of all materials and procedures prior to commencing data collection.

iii If any substantive changes to the proposed project are made, a new ethical approval application must be submitted to the Committee. Completed forms should be resubmitted through the Research Ethics Blackboard course.

iv Any changes to the agreed procedures must be negotiated with the project supervisor.

Failure to comply with these conditions will result in ethical approval being revoked by the Ethics Committee.

Research Ethics Committee
09.05.16

Appendix C. Statistical analyses Study 1

Table C-1. Z scores of skeweness and kurtosis for SQ-R and novel scale according to gender and hacker vs. non-hacker

Table C1

Z scores of skeweness and kurtosis for SQ-R and novel scale according to gender and hacker vs. non-hacker

		SQ-R		Novel scale	
		Skeweness	**Kurtosis**	**Skeweness**	**Kurtosis**
Male	Hacker (N=56)	-.686	.121	.228	-1.14
	Non-hacker (N=33)	.396	-.878	.545	.655
Female	Hacker (N=8)	-.416	-.345	.595	-.542
	Non-hacker (N=33)	1.96	-.408	.655	-.574

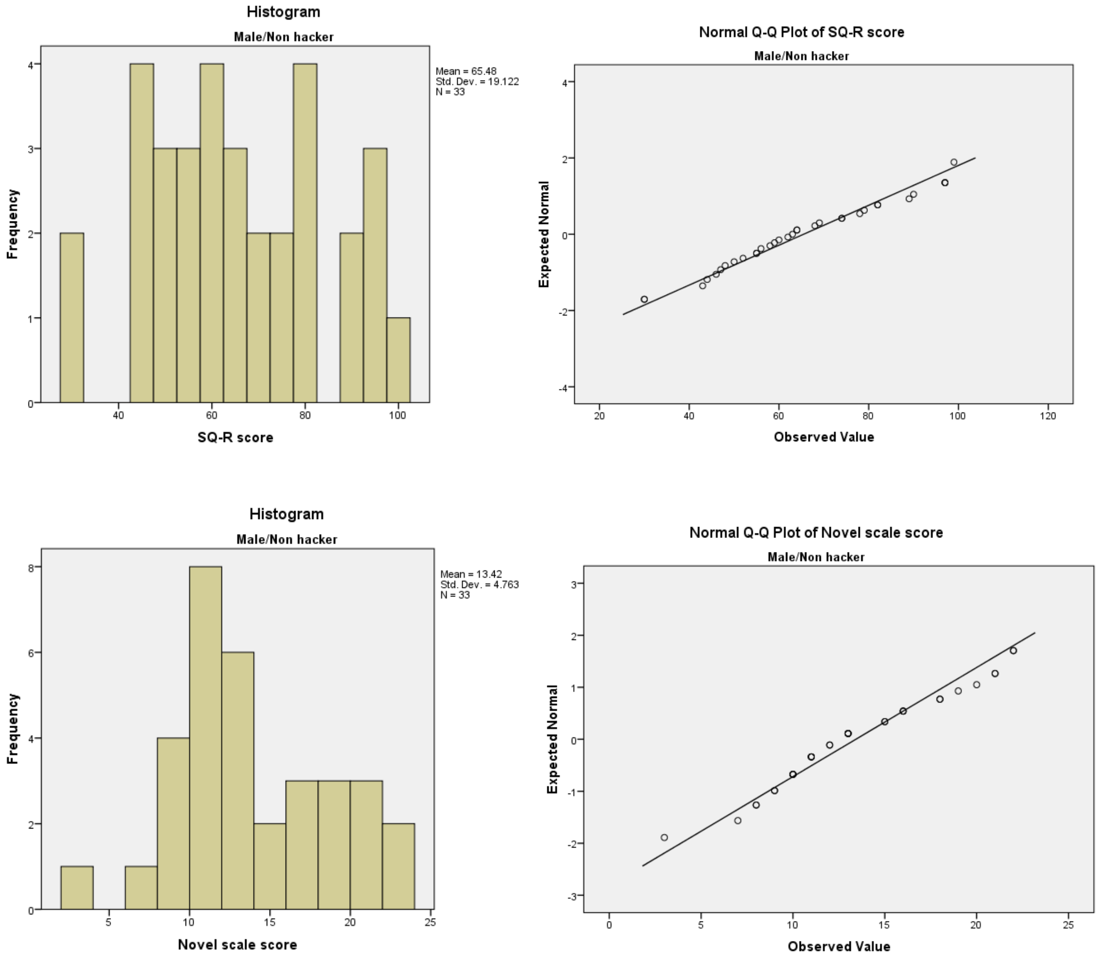
Table C-2 Test of normality for SQ-R and novel scale according to gender and hacker vs. non hacker

Table C2

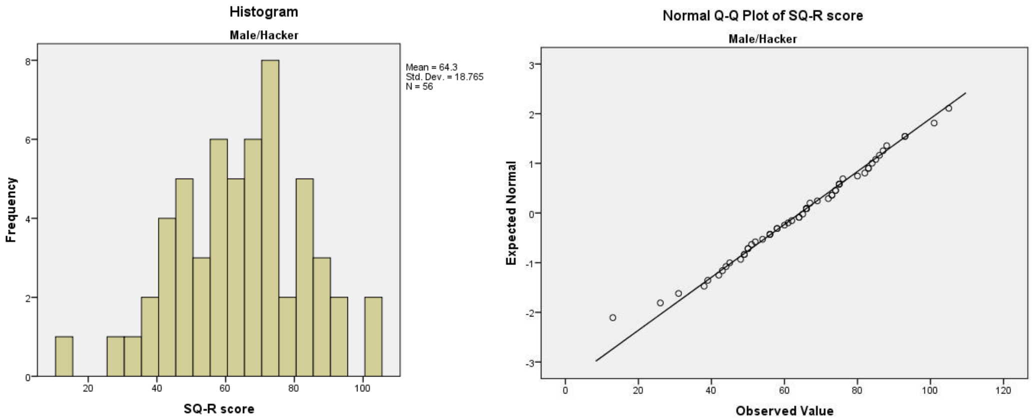
Test of normality for SQ-R and novel scale according to gender and hacker vs. non hacker

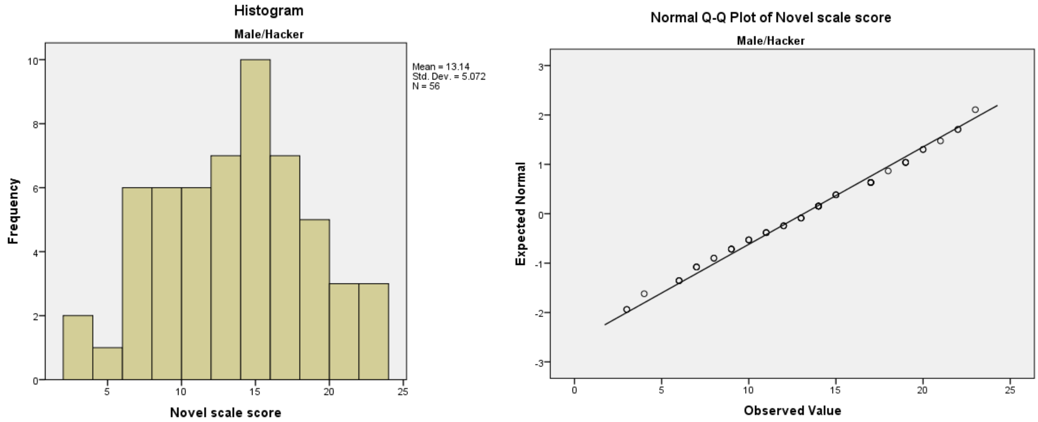
		SQ-R		Novel scal	
		Kolmogorov-Smirnov	**Shapiro-Wilk**	**Kolmogorov-Smirnov**	**Shapiro-Wilk**
Male	Hacker (N=56)	.200*	.980	.200*	.436
	Non-hacker (N=33)	.200*	.330	.200	.250
Female	Hacker (N=8)	.200*	.888	.200*	.644

	Non-hacker (N=33)	.060	.025	.200*	.113

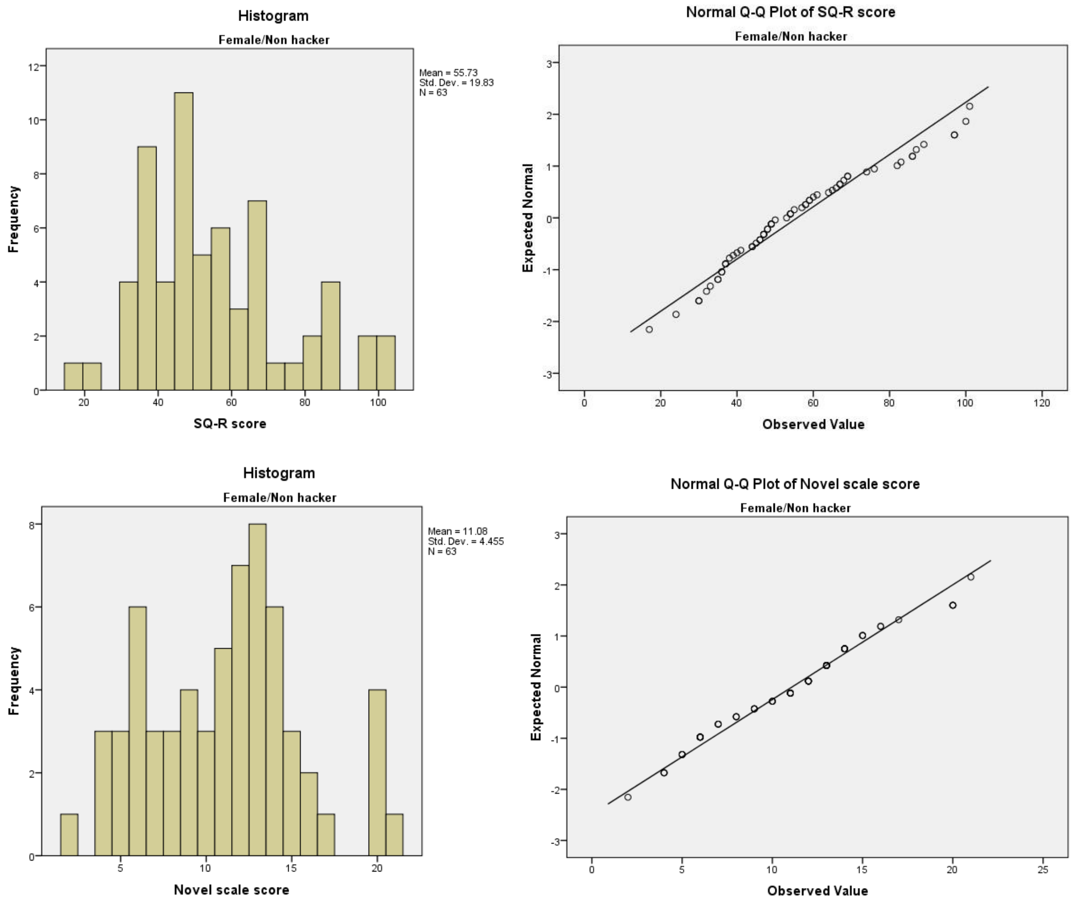


FigureC1 Histograms and Q-Q plots for SQ-R and novel scale scores for males / non-hacker

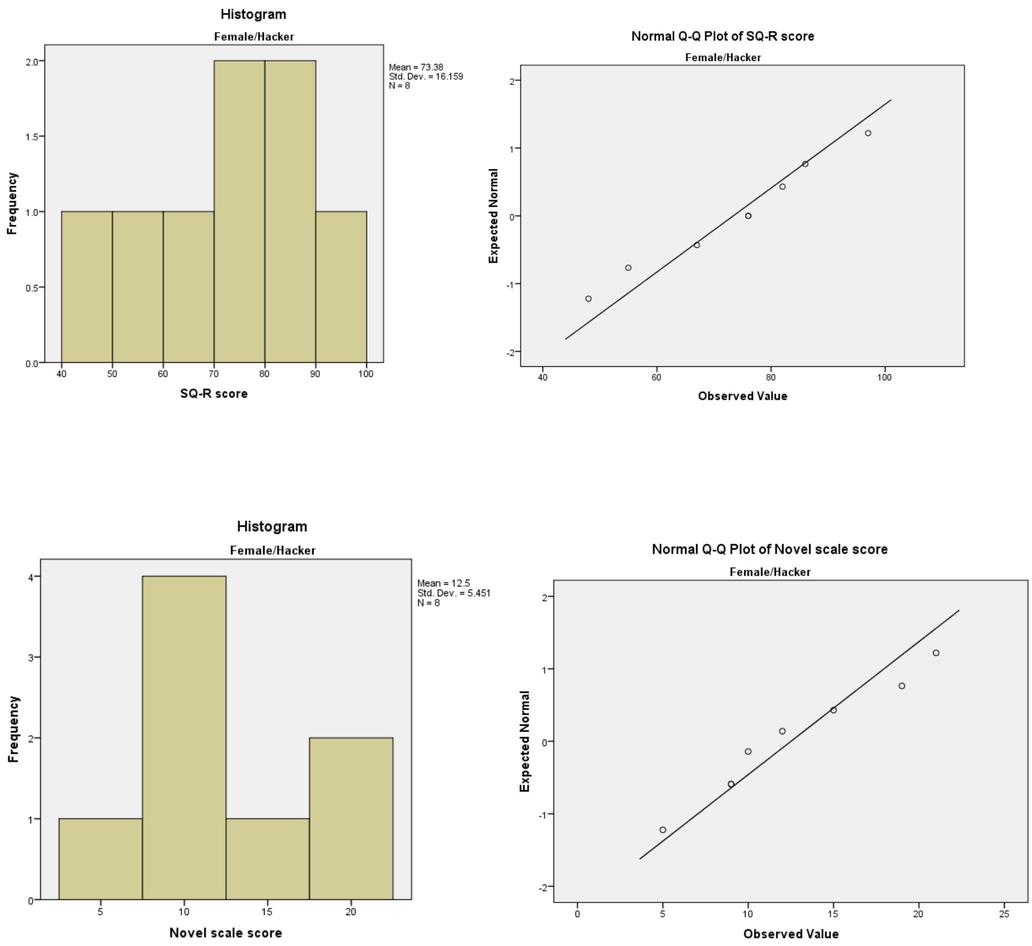




FIgureC2 Histograms and Q-Q plots for SQ-R and novel scale scores for male/hacker



FigureC3 Histograms and Q-Q plots for SQ-R and novel scale scores for females / non-hacker



FigureC4 Histograms and Q-Q plots for SQ-R and novel scale scores for female/hacker

Table C3 PCA with all items of the SQ and the Novel scale

Table C3

PCA with all items of the SQ and the Novel scale

COMPONENT 1	
ITEMS	Loadings
V53 If I were buying a computer, I would want to know exact details about its hard drive capacity and processor speed	1,022
V10 I find it difficult to learn how to programme video recorders	,946
V60 If I were buying a stereo, I would want to know about its precise technical features	,801
V15 I find it difficult to understand instruction manuals for putting appliances together	,686
V32 I am fascinated by how machines work	,682
V52 If I were buying a camera, I would not look carefully into the quality of the lens	,656
V45 I rarely read articles or webpages about new technology	,629
V6 I find it difficult to read and understand maps	,607
V17 I am not interested in understanding how wireless communication works	,545
V25 I find it easy to grasp exactly how odds work in betting	,461
V66 In maths, I am intrigued by the rules and patterns governing numbers	,403

N_3 I would define myself as a type of person who thinks outside the box	,327
COMPONENT 2	
V56 I do not follow any particular system when I am cleaning at home	,812
V65 It does not bother me if things in the house are not in their proper place	,781
V14 If I had a collection it would be highly organized	,756
V44 My clothes are not carefully organised into different types in my wardrobe	,716
V31 At home, I do not carefully file all important documents	,615
V58 I am not very meticulous when I carry out D.I.Y. or home improvements	,533
V72 When I have a lot of shopping to do, I like to plan which shops I am going to visit and in what order	,507
V71 I do not keep careful records of my household bills	,507
COMPONENT 3	
V57 I do not enjoy in-depht political discussion	,874
V40 I am not interested in how the government is organized into different ministries and departments	,799
V34 I know very little about the different stages of the legislation process in my country	,668
V47 When an election is being held, I am not interested in the results for each constituency	,630
V13 I like to know how committees are structured in terms of who the different committee members represent or what their functions are	,455
COMPONENT 4	
N_7 When I encounter a problem, I usually look at it from different perspectives in order to come up with the best solution	,847
N_4 I do not like learning new things	,757
N_10 I do not feel comfortable with taking new perspectives into things	,617
N_1 I like trying new things	,609
COMPONENT 5	
V33 When I look at a piece of furniture, I do not notice the details of how it was constructed	,951
V16 When I look at a building, I am curious about the precise way it was constructed	,704
V46 I can easily visualise how the motorways in my region link up	,573
COMPONENT 6	
V68 I could list my favourite 10 books, recalling titles and authors names from memory	,920
V42 I have a large collection of books, CDs, videos etc	,770
N_6 I often get stuck and ask other for help	**,457**
COMPONENT 7	
V74 When I listen to a piece of music, I always notice the way it's structured	1,173
V75 I could generate a list of my favourite 10 songs from memory, including the title and the artist's name who performed each song	,567
V18 When travelling by train I often wonder exactly how the rail networks are coordinated	,535
COMPONENT 8	
V69 When I read the newspaper, I am drawn to tables of information, such as football league scores or stock market indices	1,377
V22 When I was young I did not enjoy collecting sets of things	,626
V48 I do not particularly enjoy learning about facts and figures in history	,500
COMPONENT 9	

V3 I would not enjoy organizing events	1,277
V62 I avoid situation which I can not control	-,685
V9 If I were buying a car, I would want to obtain specific information about its engine capacity	-,417
V21 I know with reasonable accuracy how much money has come in and gone out of my bank account this month	,366
COMPONENT 10	
V19 I enjoy looking through catalogues of products to see the details of each product and how it compares to others	1,119
V27 When I learn about a new category I like to go into detail to understand the small differences between different members of theat category	,677
V20 Whenever I run out of something at home, I always add it to a shopping list	,538
V24 When I learn about historical events, I do not focus on exact dates	-,426
V70 When I am in a plane, I do not think about the aerodynamics	-,383
V55 When I get to the checkout at a supermarket I pack different categories of goods into separate bags	,363
COMPONENT 11	
N_2 I do not think it is necessary to come up with new solutions to a problem if the one I have used in the past was successful	1,054
N_12 When I find a way to solve a situation I do not feel the curiosity to find another way to solve it	,486
COMPONENT 12	
V41 I am interested in knowing the path a river takes from its source to a sea	1,202
V50 When I am walking in the country, I am curious about how the various kinds of trees differ	,590
V23 I am interested in my family tree and in understanding how everyone is related to each other in the family	,401
COMPONENT 13	
N_13 I feel uncomfortable in taking snap decisions	1,416
V51 I find it difficult to understand information the bank sends me on different investment and saving systems	,424
V29 When I look at an animal, I like to know the precise species it belongs to	,399
COMPONENT 14	
V37 When I look at a painting, I do not usually think about the technique involved in making it	1,047
N_8 I am afraid of making a mistake and usually this affects the decision I make	-,360
V61 I tend to keep things that other people might throw away, in case they might be useful for something in the future	1,093
COMPONENT 15	
V49 I do not tend to remember people's birthdays(day/month)	1,288
V59 I would not enjoy planning a business from scratch to completion	,983
COMPONENT 16	
V63 I do not care to know the names of the plants I see	,953
V8 I am not interested in the details of exchange rates, interest rates, stock and shares	,589
V64 When I hear the weather forecast, I am not very interested in the metheorological patterns	,554

N_9 I am good at finding solutions to problems that other would not be able to solve	-,421
COMPONENT 17	
V5 I find myself categorizing people into types	1,051
V38 I prefer social interactions that are structured around a clear activity	,361
COMPONENT 18	
V35 I do not tend to watch science documentaries on television or read articles about science and nature	1,171
V30 I can remember large amounts of information about a topic that interests me	,433
V2 I like music or books shops because they are clearly organized	,389
V54 I do not read legal documents very carefully	-,305
COMPONENT 19	
V4 When I read something, I always notice whether it is grammatically correct	1,125
V36 If someone stops to ask me the way, I'd be able to give directions to any part of my home town	,380
COMPONENT 20	
V28 I do not find it distressing if people who live with me upset my routines	,966
COMPONENT 21	
V11 When I like something I like to collect a lot of different examples of that type of object, so I can see how they differ from each other	,848
N_11 I have been told I am a creative person	,675
COMPONENT 22	
V7 When i look at a mountain, I think about how precisely it was formed	1,196
COMPONENT 23	
V26 I do not enjoy games that involve a high degree of strategy	,955
COMPONENT 24	
V12 When I learn a language, I become intrigued by its grammatical rules	,901
V67 I find it difficult to learn my way around a new city	-,500
COMPONENT 25	
V73 When I cook, I do not think about exactly how different methods and ingredients contribute to the final product	1,075
V1 I find it very easy to use train timetables, even if this involves several connections	-,491
COMPONENT 26	
V39 I do not always check off receipts against my bank statement	1,136

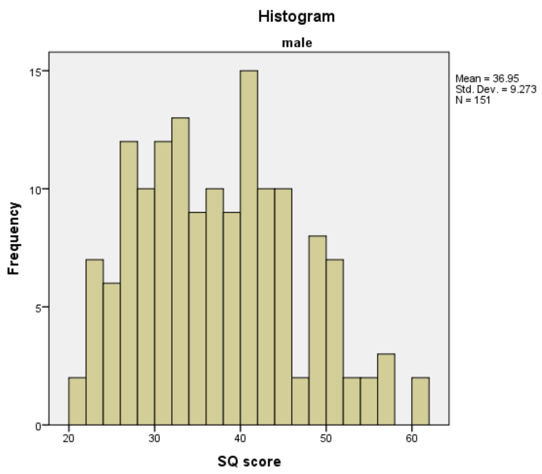
Appendix D. Statistical analyses Study 2

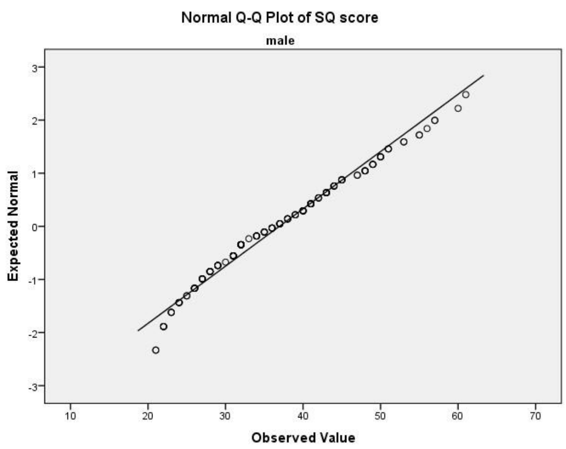
Table D1. Tests of normality for SQ, novel scale-r and morality scale

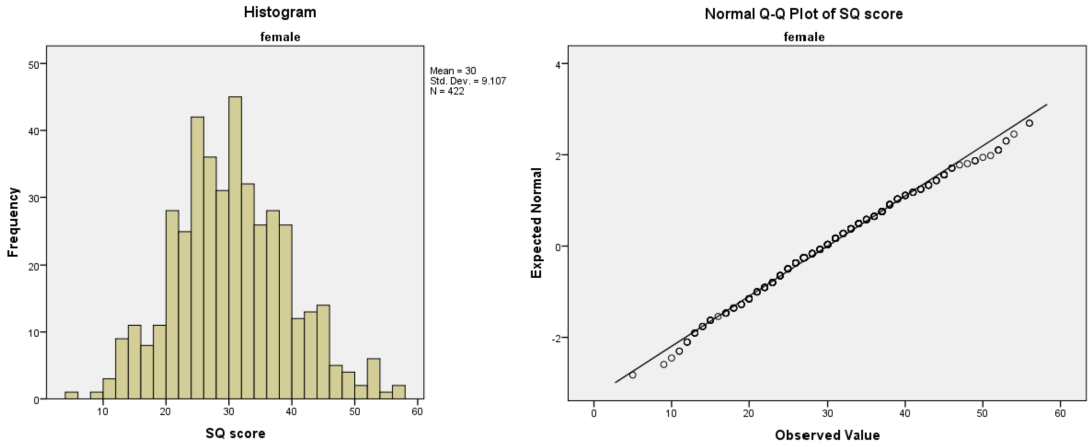
Table D1

Tests of normality

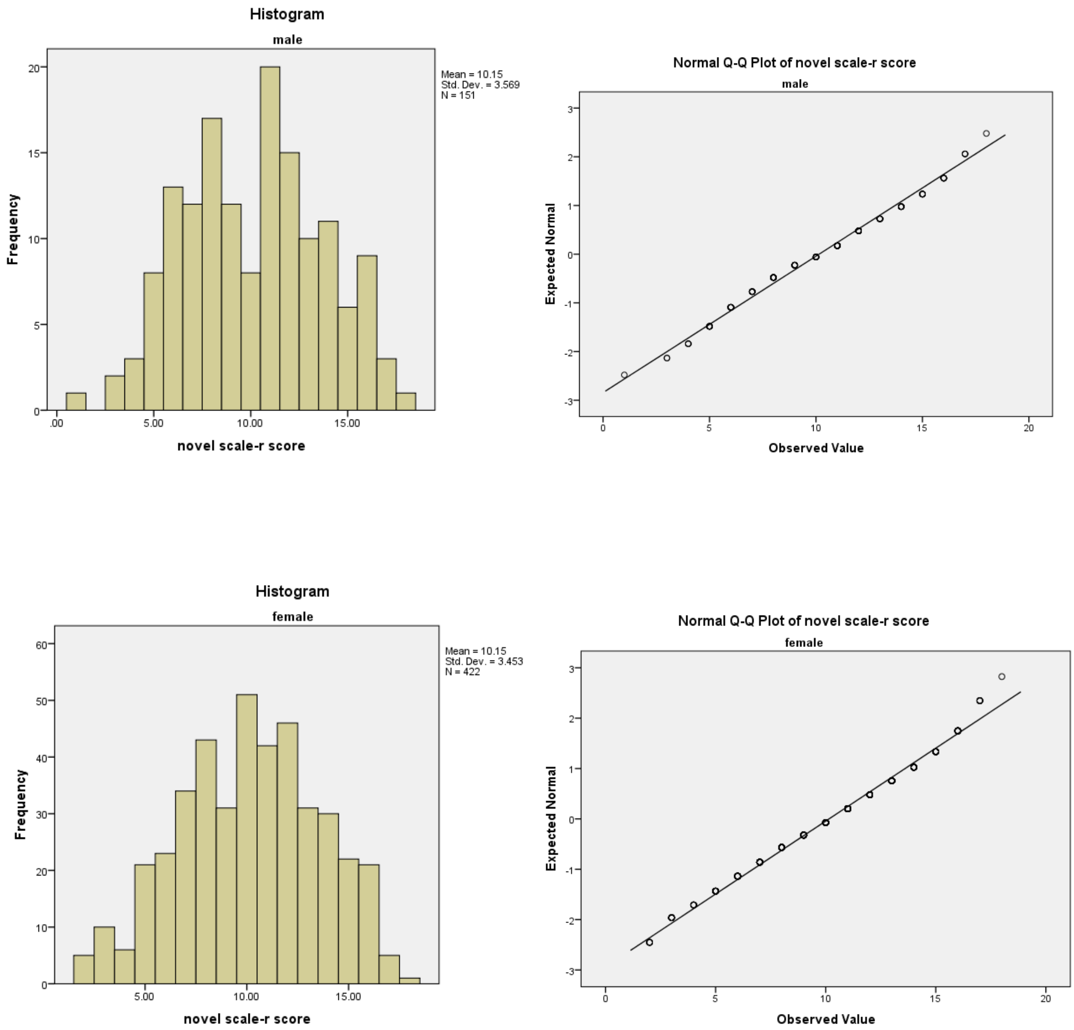
			Kolmogorov-Smirnov			Shapiro-Wilk	
	gender	**Statistic**	**df**	**Sig.**	**Statistic**	**df**	**Sig.**
SQ	Male	.107	151	.000	.975	151	.007
	Female	.051	422	.010	.993	422	.039
Novel scale-r	Male	.097	151	.001	.980	151	.026
	Female	.073	422	.000	.982	422	.000
Morality scale	Male	.292	151	.000	.778	151	.000
	Female	.364	422	.000	.668	422	.000



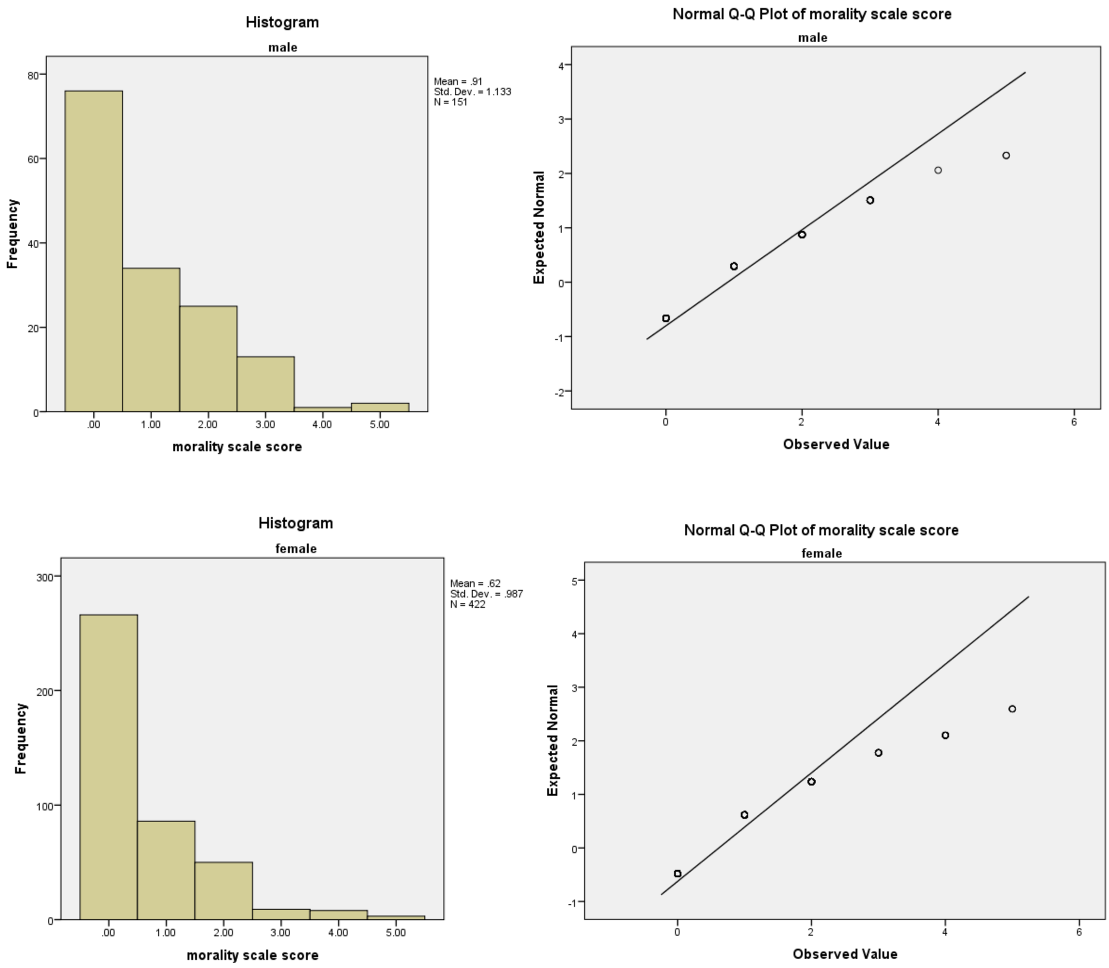




FigureD1 Histograms and QQ-plots of SQ scores for males (above) and females (below).



FigureD2 Histograms and QQ-plots of novel scale-r scores for males (above) and females (below).



FigureD3 Histograms and QQ-plots of morality scale scores for males (above) and females (below).

Table D2 PCA with all items of the SQ and the novel scale-revised

Table D2

PCA with all items of the SQ and the novel scale-revised

ITEMS	Loadings
COMPONENT 1	
SQ15 In maths, I am intrigued by the rules and patterns governing numbers	-,834
SQ34 I find it easy to grasp exactly how odds work in betting.	,753
SQ12 I do not enjoy games that involve a high degree of strategy	,656
SQ11 I rarely read articles or web pages about new technology	,637
SQ57 I am not interested in understanding how wireless communication works.	,453

SQ29 When I read the newspaper, I am drawn to tables of information	,449
SQ13 I am fascinated by how machines work	,408
SQ41 When travelling by train, I often wonder exactly how the rail networks are coordinated.	,329
COMPONENT 2	
SQ53 When I am walking in the country, I am curious about how the various kinds of trees differ.	,923
SQ60 I do not care to know the names of the plants I see.	,891
SQ19 When I look at an animal, I like to know the precise species it belongs to	,689
SQ55 I am interested in knowing the path a river takes from its source to the sea.	,432
COMPONENT 3	
SQ5 If I were buying a car, I would want to obtain specific information about its engine capacity	,901
SQ20 If I were buying a computer, I would want to know exact details about its hard drive capacity and processor speed	,837
SQ33 If I were buying a stereo, I would want to know about its precise technical features.	,826
COMPONENT 4	
SQ31 I find it difficult to learn my way around a new city.	,845
SQ24 I find it difficult to read and understand maps	,774
SQ49 I can easily visualize how the motorways in my region link up.	,761
COMPONENT 5	
SQ23 When I cook, I do not think about exactly how different methods and ingredients contribute to the final product	,771
N_9 When I find a way to solve a situation I do not feel the curiosity to find another way to solve it.	,714
N_8 I do not feel comfortable with taking new perspectives into things (e.g. change my point of view, find alternatives…).	,546
N_6 When I encounter a problem, I do not usually look at it from different perspectives in order to come up with the best solution.	,408
N_3 I would not define myself as a person who thinks out of the box.	,356
COMPONENT 6	
SQ42 When I buy a new appliance, I do not read the instruction manual very thoroughly.	,944
SQ18 I find it difficult to understand instruction manuals for putting appliances together	,560
SQ56 I do not read legal documents very carefully.	,530
SQ35 I am not very meticulous when I carry out D.I.Y.	,412
COMPONENT 7	
N_1 I like trying new things (e.g. hobbies, activities).	,836
N_2 I think it is necessary to find always new and better solutions to a problem, even if the one I have used in the past was successful.	,616
COMPONENT 8	
N_5 I believe that no matter what life throws at me, I will be able to handle it.	,869
N_7 I am good at finding solutions to problems that other would not be able to solve.	,606
COMPONENT 9	
SQ45 When I hear the weather forecast, I am not very interested in the meteorological patterns.	,754
SQ28 When I learn about historical events, I do not focus on exact dates	,658
SQ43 If I were buying a camera, I would not look carefully into the quality of the lens.	,383
COMPONENT 10	

SQ6 When I look at a painting, I do not usually think about the technique involved in making it	,804
SQ26 When I look at a piece of furniture, I do not notice the details of how it was constructed	,546
COMPONENT 11	
SQ4 I prefer to read fiction than non fiction	,994
SQ48 When I look at a mountain, I think about how precisely it was formed.	,400
COMPONENT 12	
SQ44 When I read something, I always notice whether it is grammatically correct.	,750
SQ30 When I learn a language, I become intrigued by its grammatical rules.	,748
COMPONENT 13	
SQ25 If I had a collection, it would be highly organised	,719
SQ38 When an election is being held, I am not interested in the results for each constituency.	-,648
COMPONENT 14	
SQ51 When I'm in a plane, I do not think about the aerodynamics.	,862
SQ40 I find it difficult to understand information the bank sends me on different investment and saving systems.	,586
COMPONENT 15	
SQ1 When I listen to a piece of music, I always notice the way it's structured	,886
SQ7 If there was a problem with the electrical wiring in my home, I'd be able to fix it myself	-,503
N_4 I do not like learning new things (e.g. at work and in my spare time).	,338

Appendix E. Statistical analyses Study 3

TableE1 Mean, median, SD, skeweness and kurtosis according to males vs. females and hacker vs. non-hacker.

Table E1

Mean, median, SD, skeweness and kurtosis according to males vs. females and hacker vs. non-hacker.

SQ		Mean (s.e.)	Median	St.Dev	skeweness	kurtosis
Male	Hacker (N=79)	40.01 (1.16)	39	10.28	-.172 (.271)	.236 (.535)
	Non hacker (N=81)	35.85 (1.37)	35	12.38	.095 (.267)	-.357 (.529)
Female	Hacker (N=22)	38.86 (3.14)	36	14.74	.548 (.49)	-.493 (.95)
	Non hacker (N=161)	27.19 (.90)	26	11.47	.443 (.191)	.030 (.380)
Novel scale-r						
Male	Hacker (N=79)	10.29(.41)	10	3.69	-.436(.27)	-.284(.535)
	Non hacker (N=81)	10.07(.42)	10	3.8	-.428(.27)	-.482(.53)
Female	Hacker (N=22)	10.1(.90)	10.5	4.26	-.268(.49)	-.776(.953)
	Non hacker (N=161)	9.38(.31)	10	3.96	-.235(.191)	-.320(.380)
Morality scale						
Male	Hacker (N=79)	1.62(.16)	1	1.41	.794(.271)	.132(.535)
	Non hacker (N=81)	.94(.16)	0	1.48	2.4(.267)	6.61(.53)
Female	Hacker (N=22)	1.41(.29)	1.5	1.4	.888(.491)	.619(.953)
	Non hacker (N=161)	.88(.10)	0	1.31	2.05(.191)	4.71(.380)
MRT score						
Male	Hacker (N=17)	15.59 (.993)	15	4.09	-.011 (.550)	1.481 (1.063)
	Non hacker (N=37)	18.22 (.67)	19	4.11	-.618 (.388)	-.733 (.759)
Female	Hacker (N=6)	14.67 (1.66)	13.5	4.08	1.36 (.84)	1.75 (1.74)
	Non hacker (N=51)	17.41 (.66)	18	4.72	.024 (.333)	1.98 (.65)
MRT RT						
Male	Hacker (N=17)	2640.88 (319.46)	2425.56	1317.15	.431 (.550)	-.521 (1.06)
	Non hacker (N=37)	3038.46 (139.58)	3001.84	1177.50	.478 (.388)	.067 (.759)
Female	Hacker (N=6)	1556.93 (455.88)	1299.17	1116.68	.736 (.84)	.671 (1.74)
	Non hacker (N=51)	3105.77 (165.13)	3054.95	1179.26	.130 (.333)	-.136 (.656)
Raven score						
Male	Hacker (N=19)	5.37 (.35)	5	1.53	-.392 (.524)	-.11 (1.01)
	Non hacker (N=38)	6.34 (.31)	7	1.93	-.727 (.383)	.000 (.750)
Female	Hacker (N=6)	3.83 (.792)	4	1.94	.347 (.84)	1.91 (1.74)
	Non hacker (N=53)	5.98 (.258)	7	1.87	-.480 (.327)	-.834 (.644)
Raven RT						
Male	Hacker (N=19)	16138.55 (1853.68)	17593.60	8080.03	.487 (.524)	-.528 (1.01)
	Non hacker (N=38)	15744.575 7	15006.25	9537.12	.573 (.383)	-.010 (.750)

		(1547.12)				
Female	Hacker (N=6)	9618.19 (2780.61)	9964.16	6811.07	.073 (.845)	-1.07 (1.74)
	Non hacker (N=53)	16218.24 (1446.93)	13202.00	10533.81	.862 (.327)	-.068 (.644)
Recognition score						
Male	Hacker (N=20)	10.85 (.49)	10	2.23	.493 (.512)	-.720 (.992)
	Non hacker (N=38)	11.45 (.36)	11	2.20	.259 (.383)	-.581 (.750)
Female	Hacker (N=6)	13.00 (.816)	12	2.00	.900 (.845)	-1.175 (1.74)
	Non hacker (N=55)	11.40 (.286)	11	2.12	-.079 (.322)	.005 (.634)
Recognition RT						
Male	Hacker (N=20)	1352.98 (151.88)	1333.09	679.24	1.720 (.512)	6.149 (.992)
	Non hacker (N=38)	1937.57 (366.55)	1668.18	2259.588	5.46 (.383)	32.13 (.750)
Female	Hacker (N=6)	1244.40 (246.64)	1262.01	604.14	.022 (.845)	-1.64 (1.74)
	Non hacker (N=55)	(1607.03) (81.64)	1521.83	605.49	.431 (.322)	-.693 (.634)
Order score						
Male	Hacker (N=20)	17.10 (.710)	18	3.17	-.681 (.512)	-.200 (.992)
	Non hacker (N=38)	16.87 (.54)	17	3.363	-.794 (.383)	.721 (.750)
Female	Hacker (N=6)	16.00 (1.46)	16	3.57	.000 (.845)	-1.87 (1.74)
	Non hacker (N=55)	16.78 (.386)	17	2.859	-.093 (.322)	-.604 (.634)
Order RT						
Male	Hacker (N=20)	1981.37 (126.02)	1882.57	563.59	.880 (.512)	1.194 (.992)
	Non hacker (N=38)	2102.37 (150.08)	2076.95	925.21	.124 (.383)	-.288 (.750)
Female	Hacker (N=6)	1675.87 (375.22)	1649.18	919.11	-.070 (.845)	-1.942 (1.74)
	Non hacker (N=55)	1988.65 (89.71)	1959.21	665.33	.734 (.322)	1.332 (.634)
GEFT score						
Male	Hacker (N=16)	15.56 (.953)	18	3.81	-1.81 (.564)	2.97 (1.09)
	Non hacker (N=37)	16.05 (.64)	18	3.88	-2.24 (.388)	4.339 (.759)
Female	Hacker (N=6)	12.17 (1.99)	13	4.87	-.944 (.845)	.316 (1.74)
	Non hacker (N=52)	15.52 (.554)	18	3.99	-1.768 (.330)	2.292 (.650)
GEFT RT						
Male	Hacker (N=16)	15.56 (.95)	18	3.81	-1.81 (.56)	2.97 (1.09)
	Non hacker (N=37)	13460.44 (806.27)	13570.76	4904.35	.453 (.388)	-.665 (.759)
Female	Hacker (N=6)	17444.94 (1342.61)	17821.96	3288.72	-.296 (.845)	-2.25 (1.741)
	Non hacker (N=52)	15255.21 (631.16)	16152.46	4551.39	-.121 (.330)	-.792 (.650)
Global bias						

Male	Hacker (N=14)	-42.97 (51.23)	-65.25	191.70	-.136 (.597)	-.57 (1.15)
	Non hacker (N=19)	25.46 (12.20)	24	53.17	.156 (.524)	-.685 (1.014)
Female	Hacker (N=2)	14.22 (5.32)	14.22	7.53		
	Non hacker (N=30)	20.69 (22.37)	5.82	122.55	.690 (.427)	.137 (.833)
Local bias						
Male	Hacker (N=17)	-20.32 (19.74)	-4.96	81.38	-2.05 (.55)	6.43 (1.06)
	Non hacker (N=31)	12.04 (9.83)	15.12	54.76	.814 (.421)	1.613 (.821)
Female	Hacker (N=3)	-119.24 (23.87)	-142.06	41.35	1.73 (1.22)	
	Non hacker (N=49)	4.6672 (8.45)	-5.33	59.17	.477 (.340)	2.074 (.668)
Local/Global precedence						
Male	Hacker (N=17)	70.54 (40.02)	78.44	165.03	-.150 (.55)	-.253 (1.063)
	Non hacker (N= 31)	130.32 (27.62)	107.41	153.81	.783 (.421)	1.214 (.821)
Female	Hacker (N=3)	136.99 (77.76)	115.93	134.68	.687 (1.22)	
	Non hacker (N=49)	121.29 (19.61)	80.68	137.29	.767 (.340)	-.138 (.668)
Hidden words search score						
Male	Hacker (N=20)	4.40 (.351)	5	1.569	-.748 (.512)	-.543 (.992)
	Non hacker (N=37)	4.65 (.213)	5	1.29	-.833 (.388)	.285 (.759)
Female	Hacker (N=6)	3.33 (.615)	3	1.50	.215 (.845)	-2.25 (1.74)
	Non hacker (N=52)	4.29 (.187)	4	1.35	-.303 (.330)	-1.044 (.650)
Hidden words search RT						
Male	Hacker (N=20)	20079.72 (2384.23)	17266.43	10662.62	..326 (.512)	-1.04 (.992)
	Non hacker (N=37)	16405.12 (1824.56)	12706.25	11098.39	1.292 (.388)	1.326 (.759)
Female	Hacker (N=6)	13151.98 (3488.82)	9482.8	8545.82	1.481 (.845)	1.64 (1.74)
	Non hacker (N=52)	19733.82 (2089.73)	17430.8	15069.26	2.741 (.330)	11.496 (.650)
Hacking challenge score						
Male	Hacker (N=15)	3.80 (.80)	2	3.098	.781 (.58)	-.802 (1.12)
	Non hacker (N=33)	5.09 (.686)	5	3.94	1.011 (.409)	1.76 (.79)
Female	Hacker (N=3)	5.00 (1.73)	5	3.00	.000 (1.22)	
	Non hacker (N=38)	4.18 (.489)	3	3.012	.502 (.383)	-1.439 (.750)
Hacking challenge RT						
Male	Hacker (N=15)	7753.12 (1202.47)	6683.6	4657.15	.750 (.580)	.097 (1.12)

	Non hacker (N=33)	6487.75 (909.37)	4690	5223.94	2.17 (.409)	4.68 (.79)
Female	Hacker (N=3)	8211.26 (1592.89)	8834.	2758.98	-.965 (1.22)	
	Non hacker					

Table E2

Tests of normality

	Kolmogorov-Smirnov			Shapiro-Wilk		
Male / Non hacker	Statistic	Df	Sig.	Statistic	Df	Sig.
SQ	.075	81	.200*	.989	81	.724
Novel scale-r	.110	81	.018	.967	81	.035
Morality scale	.311	81	000	.652	81	.000
MRT score	.224	37	.000	.914	37	.008
MRT rts	.079	37	.200*	.979	37	.696
Raven score	.186	38	.002	.917	38	.008
Raven rts	.098	38	.200*	.965	38	.266
Recognition score	.159	38	.016	.953	38	.109
Recognition rts	.371	38	.000	.385	38	.000
Order score	.147	38	.037	.939	38	.040
Order rts	.066	38	.200*	.984	38	.840
GEFT score	.394	37	.000	.576	37	.000
GEFT rts	.106	37	.200*	.943	37	.056
Hidden words search score	.201	37	.001	.873	37	.001
Hidden words search rts	.213	37	.000	.859	37	.000
Hacking challenge score	.178	33	.010	.844	33	.000
Hacking challenge rts	.280	33	.000	.729	33	.000
Local/global preference	.185	31	.008	.907	31	.011
Global bias	.121	19	.200*	.972	19	.820
Local bias	.125	31	.200*	.935	31	.059
Male / hacker						
SQ	.081	79	.200*	.988	79	.660
Novel scale-r	.111	79	.018	.969	79	.052
.Morality scale	.215	79	.000	.890	79	.000

MRT score	.146	17	.200*	.946	17	.390
MRT rts	.101	17	.200*	.964	17	.704
Raven score	.142	19	.200*	.956	19	.493
Raven rts	.136	19	.200*	.950	19	.388
Recognition score	.148	20	.200*	.923	20	.114
Recognition rts	.221	20	.011	.823	20	.002
Order score	.212	20	.019	.942	20	.259
Order rts	.143	20	.200*	.949	20	.352
GEFT score	.301	16	.000	.706	16	.000
GEFT rts	.149	16	.200*	.952	16	.528
Hidden words search score	.249	20	.002	.870	20	.012
Hidden words search rts	.148	20	.200*	.947	20	.326
Hacking challenge score	.253	15	.011	.839	15	.012
Hacking challenge rts	.133	15	.200*	.929	15	.263
Local/global preference	.125	17	.200*	.954	17	.527
Global bias	.126	14	.200*	.962	14	.762
Local bias	.218	17	.031	.817	17	.004
Female/ non hacker						
SQ	.071	161	.044	.983	161	.041
Novel scale-r	.081	161	.011	.983	161	.051
Morality scale	.277	161	.000	.698	161	.000
MRT score	.107	51	.200*	.953	51	.042
MRT rts	.057	51	.200*	.984	51	.708
Raven score	.235	53	.000	.917	53	.001
Raven rts	.149	53	.005	.916	53	.001
Recognition score	.153	55	.003	.968	55	.147
Recognition rts	.127	55	.027	.955	55	.037
Order score	.097	55	.200*	.975	55	.308
Order rts	.087	55	.200*	.963	55	.086
GEFT score	.291	52	.000	.685	52	.000
GEFT rts	.091	52	.200*	.973	52	.293
Hidden words search score	.182	52	.000	.893	52	.000
Hidden words search rts	.159	52	.002	.762	52	.000

Hacking challenge score	.239	38	.000	.827	38	.000
Hacking challenge rts	.156	38	.021	.907	38	.004
Local/global preference	.148	49	.009	.931	49	.006
Global bias	.138	30	.151	.948	30	.147
Local bias	.102	49	.200*	.957	49	.072
Female/ hacker						
SQ	.134	22	.200*	.953	22	.355
Novel scale-r	.093	22	.200*	.968	22	.660
Morality scale	.206	22	.016	.846	22	.003
MRT score	.243	6	.200*	.859	6	.185
MRT rts	.185	6	.200*	.960	6	.817
Raven score	.299	6	.100	.909	6	.433
Raven rts	.163	6	.200*	.969	6	.885
Recognition score	.358	6	.016	.823	6	.094
Recognition rts	.187	6	.200*	.935	6	.622
Order score	.202	6	.200*	.853	6	.167
Order rts	.188	6	.200*	.920	6	.504
GEFT score	.219	6	.200*	.909	6	.433
GEFT rts	.280	6	.155	.865	6	.206
Hidden words search score	.312	6	.069	.767	6	.029
Hidden words search rts	.274	6	.178	.827	6	.101
Hacking challenge score	.175	3		1.000	3	1.000
Hacking challenge rts	.256	3		.962	3	.624
Local/global preference	.229	3		.982	3	.741
Global bias	.260	2				
Local bias	.376	3		.772	3	.048

Table E3 PCA with all items of the SQ and the Novel scale revised

Table E3

PCA with all items of the SQ and the Novel scale revised

ITEMS	Loadings

COMPONENT 1	
SQ20 [If I were buying a computer, I would want to know exact details about its hard drive capacity and processor speed.]	,826
SQ5 If I were buying a car, I would want to obtain specific information about its engine capacity	,736
SQ33 [If I were buying a stereo, I would want to know about its precise technical features.]	,669
SQ7 [If there was a problem with the electrical wiring in my home, I'd be able to fix it myself.]	,548
SQ13 [I am fascinated by how machines work.]	,502
SQ43 [If I were buying a camera, I would not look carefully into the quality of the lens.]	,396
COMPONENT 2	
Novel3 [I would not define myself as a person who thinks out of the box.]	,758
Novel9 [When I find a way to solve a situation I do not feel the curiosity to find another way to solve it.]	,716
Novel2 [I think it is necessary to find always new and better solutions to a problem, even if the one I have used in the past was successful.]	,592
Novel8 [I do not feel comfortable with taking new perspectives into things (e.g. change my point of view, find alternativesâ€¦).]	,590
Novel6 [When I encounter a problem, I do not usually look at it from different perspectives in order to come up with the best solution.]	,527
Novel4 [I do not like learning new things (e.g. at work and in my spare time).]	,444
Novel7 [I am good at finding solutions to problems that other would not be able to solve.]	,414
COMPONENT 3	
SQ53 [When I am walking in the country, I am curious about how the various kinds of trees differ.]	,788
SQ60 [I do not care to know the names of the plants I see.]	,679
SQ55 [I am interested in knowing the path a river takes from its source to the sea.]	,621
SQ45 [When I hear the weather forecast, I am not very interested in the meteorological patterns.]	,597
SQ48 [When I look at a mountain, I think about how precisely it was formed.]	,489
SQ19 [When I look at an animal, I like to know the precise species it belongs to.]	,472
COMPONENT 4	
SQ19 [When I look at an animal, I like to know the precise species it belongs to.]	-,363
SQ31 [I find it difficult to learn my way around a new city.]	,898
SQ24 [I find it difficult to read and understand maps.]	,706
SQ49 [I can easily visualize how the motorways in my region link up.]	,542
SQ1 I find it very easy to use train timetables, even if this involves several connections	,445
SQ18 [I find it difficult to understand instruction manuals for putting appliances together.]	,402
COMPONENT 5	
SQ15 [In maths, I am intrigued by the rules and patterns governing numbers.]	,868
SQ34 [I find it easy to grasp exactly how odds work in betting.]	,475
SQ51 [When I'm in a plane, I do not think about the aerodynamics.]	,441

SQ57 [I am not interested in understanding how wireless communication works.]	,409
COMPONENT 6	
SQ32 [I do not tend to watch science documentaries on television or read articles about science and nature.]	,797
SQ11 [I rarely read articles or web pages about new technology.]	,557
COMPONENT 7	
SQ35 [I am not very meticulous when I carry out D.I.Y.]	,715
SQ26 [When I look at a piece of furniture, I do not notice the details of how it was constructed.]	,596
Novel1 [I like trying new things (e.g. hobbies, activities).]	-,316
COMPONENT 8	
SQ28 [When I learn about historical events, I do not focus on exact dates.]	,738
SQ29 [When I read the newspaper, I am drawn to tables of information, such as football league scores or stock market indices.]	,734
SQ12 [I do not enjoy games that involve a high degree of strategy.]	,402
COMPONENT 9	
SQ41 [When travelling by train, I often wonder exactly how the rail networks are coordinated.]	,735
SQ37 [When I look at a building, I am curious about the precise way it was constructed.]	,354
COMPONENT 10	
Novel5 [I believe that no matter what life throws at me, I will be able to handle it.]	,704
SQ40 [I find it difficult to understand information the bank sends me on different investment and saving systems.]	,655
COMPONENT 11	
SQ44 [When I read something, I always notice whether it is grammatically correct.]	,806
SQ30 [When I learn a language, I become intrigued by its grammatical rules.]	,785
COMPONENT 12	
SQ23 [When I cook, I do not think about exactly how different methods and ingredients contribute to the final product.]	,724
SQ38 [When an election is being held, I am not interested in the results for each constituency.]	,671
SQ6 [When I look at a painting, I do not usually think about the technique involved in making it.]	,548
COMPONENT 13	
SQ42 [When I buy a new appliance, I do not read the instruction manual very thoroughly.]	,802
SQ25 [If I had a collection (e.g. CDs, coins, stamps), it would be highly organized.]	,483
SQ56 [I do not read legal documents very carefully.]	,425
COMPONENT 14	
SQ4 I prefer to read non-fiction than fiction	,951

Appendix F. Stepwise regression model coefficients

Table G1. Stepwise regression model coefficients for hacking challenge.

Table G1

Stepwise regression model coefficients for hacking challenge

	B	SE B	*β*
Model 1			
Constant	-2.783	3.209	
SQ score	.042	.027	.153
Novel scale-r	.134	.080	.164
Moral scale	-.237	.210	-.101
MRT score	.213	.069	.326
MRT rts	-.001	.000	-.206
Raven score	.028	.173	.018
Raven rts	-7.694E-5	.000	-.224
Serial recognition score	.095	.123	.070
Serial recognition rts	.001	.001	.144
Order recognition score	.035	.100	.036
Order recognition rts	9.556E-5	.000	.022
GEFT score	.003	.101	.003
GEFT rts	-7.477E-5	.000	-.100
Global bias	-.001	.002	-.052
Local bias	-.003	.004	-.063
Model 2			
Constant	-2.741	2.900	
SQ score	.042	.027	.154
Novel scale-r	.134	.080	.163

Moral scale	-.237	.208	-.101
MRT score	.214	.067	.327
MRT rts	-.001	.000	-.204
Raven score	.029	.168	.018
Raven rts	-7.691E-5	.000	-.224
Serial recognition score	.095	.122	.070
Serial recognition rts	.001	.001	.144
Order recognition score	.035	.098	.036
Order recognition rts	9.364E-5	.000	.022
GEFT rts	-7.491E-5	.000	-.101
Global bias	-.001	.002	-.052
Local bias	-.003	.004	-.064
Model 3			
Constant	-2.685	2.866	
SQ score	.042	.027	.152
Novel scale-r	.134	.079	.163
Moral scale	-.236	.207	-.101
MRT score	.215	.066	.329
MRT rts	-.001	.000	-.202
Raven rts	-7.413E-5	.000	-.216
Serial recognition score	.096	.121	.071
Serial recognition rts	.001	.001	.143
Order recognition score	.041	.092	.042
Order recognition rts	8.483E-5	.000	.020
GEFT rts	-7.738E-5	.000	-.104
Global bias	-.001	.002	-.055
Local bias	-.003	.004	-.062
Model 4			
Constant	-2.707	2.848	
SQ score	.041	.027	.151
Novel scale-r	.134	.079	.164
Moral scale	-.238	.205	-.102
MRT score	.215	.066	.329

MRT rts	-.001	.000	-.200
Raven rts	-7.235E-5	.000	-.211
Serial recognition score	.095	.120	.070
Serial recognition rts	.001	.001	.151
Order recognition score	.046	.086	.047
GEFT rts	-7.856E-5	.000	-.105
Global bias	-.001	.002	-.056
Local bias	-.003	.004	-.062
Model 5			
Constant	-1.897	2.400	
SQ score	.040	.026	.147
Novel scale-r	.140	.078	.171
Moral scale	-.236	.205	-.101
MRT score	.219	.065	.334
MRT rts	.000	.000	-.195
Raven rts	-7.236E-5	.000	-.211
Serial recognition score	.089	.119	.066
Serial recognition rts	.001	.001	.151
GEFT rts	-8.385E-5	.000	-.113
Global bias	-.001	.002	-.059
Local bias	-.003	.004	-.066
Model 6			
Constant	-.1.940	2.392	
SQ score	.038	.026	.139
Novel scale-r	.139	.077	.170
Moral scale	-.222	.203	-.095
MRT score	.224	.065	.342
MRT rts	.000	.000	-.193
Raven rts	-7.564E-5	.000	-.221
Serial recognition score	.089	.119	.066
Serial recognition rts	.001	.001	.149

GEFT rts	-8.096E-5	.000	-.109
Local bias	-.003	.004	-.068
Model 7			
Constant	-1.111	2.114	
SQ score	.041	.026	.150
Novel scale-r	.145	.077	.177
Moral scale	-.221	.203	-.095
MRT score	.221	.064	.338
MRT rts	.000	.000	-.191
Raven rts	-7.689E-5	.000	-.224
Serial recognition rts	.001	.001	.155
GEFT rts	-7.900E-5	.000	-.106
Local bias	-.003	.004	-.079
Model 8			
Constant	-.866	2.095	
SQ score	.044	.026	.159
Novel scale-r	.138	.076	.168
Moral scale	-.237	.202	-.102
MRT score	.216	.064	.331
MRT rts	-.001	.000	-.208
Raven rts	-7.495E-5	.000	-.219
Serial recognition rts	.001	.001	.153
GEFT rts	-8.125E-5	.000	-.109
Model 9			
Constant	-2.407	1.630	
SQ score	.043	.026	.158
Novel scale-r	.142	.076	.173
Moral scale	-.219	.201	-.094
MRT score	.240	.061	.367

MRT rts	-.001	.000	-.225
Raven rts	-8.183E-5	.000	-.239
Serial recognition rts	.001	.001	.166
Model 10			
Constant	-2.449	1.631	
SQ score	.042	.026	.153
Novel scale-r	.143	.076	.175
MRT score	.233	.061	.356
MRT rts	-.001	.000	-.205
Raven rts	-8.198E-5	.000	-.239
Serial recognition rts	.001	.001	.155
Model 11			
Constant	-1.721	1.582	
Novel scale-r	.196	.070	.239
MRT score	.252	.060	.385
MRT rts	-.001	.000	*.206
Raven rts	-8.173E-5	.000	-.238
Serial recognition rts	.001	.001	.137
Model 12			
Constant	-.767	1.470	
Novel scale-r	.200	.070	.244
MRT score	.264	.060	.404
MRT rts	.000	.000	-.182
Raven rts	-8.115E-5	.000	-.237

Table G2. Stepwise regression model coefficients for word search task

Table G2

Stepwise regression model coefficients for word search task

	B	SE B	�
Model 1			
Constant	9.695	3.599	
SQ score	-.031	.031	-.102
Novel scale-r	.067	.092	.073
Moral scale	-.012	.238	-.004
MRT score	-.136	.081	-.179
MRT rts	.001	.000	.334
Raven score	-.030	.204	-.017
Raven rts	-1.183E-6	.000	-.003
Serial recognition score	-.102	.146	-.065
Serial recognition rts	.000	.001	.032
Order recognition score	-.069	.117	-.064
Order recognition rts	.000	.001	-.056
GEFT score	.132	.109	.129
GEFT rts	.000	.000	-.147
Global bias	.004	.002	.166
Local bias	.006	.005	.109
Model 2			
Constant	9.694	3.582	
SQ score	-.031	.031	-.102
Novel scale-r	.067	.091	.073
Moral scale	-.012	.237	-.004
MRT score	-.135	.080	-.179
MRT rts	.001	.000	.334
Raven score	-.033	.180	-.018
Serial recognition score	-.102	.145	-.065

Serial recognition rts	.000	.001	.032
Order recognition score	-.068	.112	-.064
Order recognition rts	.000	.001	-.057
GEFT score	.132	.108	.129
GEFT rts	.000	.000	-.148
Global bias	.004	.002	.165
Local bias	.006	.005	.109
Model 3			
Constant	9.685	3.560	
SQ score	-.031	.031	-.103
Novel scale-r	.067	.091	.073
MRT score	-.136	.079	-.179
MRT rts	.001	.000	.335
Raven score	-.033	.178	-.019
Serial recognition score	-.101	.144	-.065
Serial recognition rts	.000	.001	.031
Order recognition score	-.068	.111	-.064
Order recognition rts	.000	.001	-.057
GEFT score	.133	.108	.129
GEFT rts	.000	.000	-.148
Global bias	.004	.002	.166
Local bias	.006	.005	.109
Model 4			
Constant	9.662	3.542	
SQ score	-.030	.030	-.101
Novel scale-r	.068	.090	.075
MRT score	-.137	.079	-.180
MRT rts	.001	.000	.331
Serial recognition score	-.102	.143	-.065
Serial recognition rts	.000	.001	.033
Order recognition score	-.074	.107	-.069

Order recognition rts	.000	.001	-.057
GEFT score	.128	.104	.125
GEFT rts	.000	.000	-.147
Global bias	.004	.002	.166
Local bias	.006	.005	.108
Model 5			
Constant	9.868	3.470	
SQ score	-.031	.030	-.101
Novel scale-r	.067	.090	.074
MRT score	-.133	.078	-.176
MRT rts	.001	.000	.334
Serial recognition score	-.099	.142	-.063
Order recognition score	-.078	.105	-.073
Order recognition rts	.000	.001	-.041
GEFT score	.127	.104	.124
GEFT rts	.000	.000	-.148
Global bias	.004	.002	.166
Local bias	.006	.005	.109
Model 6			
Constant	9.771	3.449	
SQ score	-.030	.030	-.098
Novel scale-r	.066	.089	.073
MRT score	-.136	.077	-.180
MRT rts	.001	.000	.326
Serial recognition score	-.101	.142	-.065
Order recognition score	-.095	.097	-.089
GEFT score	.131	.103	.128
GEFT rts	.000	.000	-.146
Global bias	.004	.002	.166
Local bias	.006	.005	.106
Model 7			

Constant	8.659	3.072	
SQ score	-.032	.030	-.106
Novel scale-r	.057	.088	.063
MRT score	-.136	.077	-.180
MRT rts	.001	.000	.325
Order recognition score	-.086	.095	-.081
GEFT score	.130	.103	.126
GEFT rts	.000	.000	-.147
Global bias	.004	.002	.166
Local bias	.006	.005	.119
Model 8			
Constant	9.016	3.014	
SQ score	-.024	.027	-.071
MRT score	-.144	.076	-.190
MRT rts	.001	.000	.324
Order recognition score	-.076	.094	-.072
GEFT score	.129	.103	.125
GEFT rts	.000	.000	-.150
Global bias	.004	.002	.172
Local bias	.007	.005	.125
Model 9			
Constant	7.623	2.475	
SQ score	-.026	.027	-.084
MRT score	-.151	.075	-.200
MRT rts	.001	.000	.318
GEFT score	.138	.102	.134
GEFT rts	.000	.000	-.138
Global bias	.004	.002	.173
Local bias	.007	.005	.129
Model 10			

Constant	7.219	2.436	
MRT score	-.159	.075	-.210
MRT rts	.001	.000	.320
GEFT score	.123	.100	.120
GEFT rts	.000	.000	-.143
Global bias	.003	.002	.155
Local bias	.007	.005	.133
Model 11			
Constant	9.066	1.916	
MRT score	-.134	.072	-.177
MRT rts	.001	.000	.337
GEFT rts	.000	.000	-.177
Global bias	.003	.002	.152
Local bias	.007	.005	.132
Model 12			
Constant	8.730	1.914	
MRT score	-.128	.072	-.169
MRT rts	.001	.000	.357
GEFT rts	.000	.000	-.175
Global bias	.003	.002	.152

Stepwise regression model coefficients for steganography task

Table G3

Stepwise regression model coefficients for steganography task

	B	SE B	�
Model 1			
Constant	5.252	6.121	
SQ score	.153	.052	.662
Novel scale-r	.098	.131	.202
Moral scale	.197	.821	.074
MRT score	-.224	.169	-.429
MRT rts	-.001	.000	-.713
Raven score	.735	.345	.586
Raven rts	.000	.000	.564
Serial recognition score	.420	.349	.387
Serial recognition rts	-.003	.001	-.624
Order recognition score	-.329	.187	-.504
Order recognition rts	.000	.001	-.073
GEFT score	.053	.177	.071
GEFT rts	.000	.000	-.263
Global bias	-.013	.004	-.944
Local bias	-.002	.010	-.065
Model 2			
Constant	5.439	5.774	
SQ score	.156	.048	.674
Novel scale-r	.083	.107	.170
Moral scale	.083	.627	.031
MRT score	-.241	.146	-.460
MRT rts	-.001	.000	-.711
Raven score	.697	.290	.556
Raven rts	.000	.000	.581
Serial recognition score	.475	.243	.437

Serial recognition rts	-.003	.001	-.643
Order recognition score	-.326	.178	-.499
Order recognition rts	.000	.001	-.048
GEFT score	.059	.167	.078
GEFT rts	.000	.000	-.295
Global bias	-.013	.004	-.935
Model 3			
Constant `	5.663	5.270	
SQ score	.158	.044	.683
Novel scale-r	.076	.089	.156
MRT score	-.246	.133	-.471
MRT rts	-.001	.000	-.719
Raven score	.687	.267	.548
Raven rts	.000	.000	.572
Serial recognition score	.480	.230	.441
Serial recognition rts	-.004	.001	-.651
Order recognition score	-.323	.168	-.494
Order recognition rts	.000	.001	-.040
GEFT score	.068	.143	.091
GEFT rts	.000	.000	-.304
Global bias	-.013	.004	-.932
Model 4			
Constant	5.873	4.885	
SQ score	.159	.041	.688
Novel scale-r	.071	.080	.146
MRT score	-.254	.118	-.486
MRT rts	-.001	.000	-.722
Raven score	.677	.248	.540
Raven rts	.000	.000	-.722
Serial recognition score	.495	.199	.455
Serial recognition rts	-.044	.001	-.668

Order recognition score	-.338	.133	-.517
GEFT score	.062	.132	.083
GEFT rts	.000	.000	-.300
Global bias	-.013	.004	-.933
Model 5			
Constant	6.677	4.438	
SQ score	.158	.040	.685
Novel scale-r	.084	.073	.172
MRT score	-.251	.114	-.479
MRT rts	-.001	.000	-.723
Raven score	.711	.230	.567
Raven rts	.000	.000	.541
Serial recognition score	.500	.193	.460
Serial recognition rts	-.004	.001	-.656
Order recognition score	-.360	.121	-.551
GEFT rts	.000	.000	-.275
Global bias	-.013	.004	-.921
Model 6			
Constant	7.402	4.440	
SQ score	.165	.040	.714
MRT score	-.258	.115	-.494
MRT rts	-.001	.000	-.717
Raven score	.700	.233	.558
Raven rts	.000	.000	.553
Serial recognition score	.509	.195	.469
Serial recognition rts	-.004	.001	-.675
Order recognition score	-.335	.120	-.512
GEFT rts	.000	.000	-.316
Global bias	-.012	.004	-.894
Model 7			

Constant	2.557	3.415	
SQ score	.152	.041	.659
MRT score	-.158	.101	-.302
MRT rts	-.001	.000	-.678
Raven score	.582	.232	.464
Raven rts	9.592E-5	.000	.383
Serial recognition score	.470	.203	.433
Serial recognition rts	-.003	.001	-.574
Order recognition score	-.249	.113	-.382
Global bias	-.012	.004	-.864
Model 8			
Constant	1.143	3.437	
SQ score	.126	.039	.546
MRT rts	-.001	.000	-.590
Raven score	.552	.241	.441
Raven rts	5.580E-5	.000	.223
Serial recognition score	.328	.189	.302
Serial recognition rts	-.002	.001	-.461
Order recognition score	-.233	.117	-.357
Global bias	-.009	.004	-.669
Model 9			
Constant	1.293	3.433	
SQ score	.133	.038	.577
MRT rts	-.001	.000	-.546
Raven score	.593	.238	.473
Serial recognition score	.269	.180	.248
Serial recognition rts	-.002	.001	-.384
Order recognition score	-.236	.117	-.362
Global bias	-.007	.003	-.501
Model 10			

Constant	3.145	3.312	
SQ	.138	.039	.596
MRT rts	-.001	.000	-.531
Raven score	.638	.244	.509
Serial recognition rts	-.002	.001	-.314
Order recognition score	-.239	.121	-.365
Global bias	-.006	.003	-.440
Model 11			
Constant	-.182	2.712	
SQ	.126	.040	.545
MRT rts	-.001	.000	-.376
Raven score	.465	.228	.371
Order recognition score	-.177	.120	-.271
Global bias	-.004	.003	-.289
Model 12			
Constant	-3.242	1.798	
SQ	.128	.042	.555
MRT rts	.000	.000	-.281
Raven score	.380	.228	.303
Global bias	-.004	.003	-.329
Model 13			
Constant	-4.353	1.675	
SQ	.122	.042	.529
Raven score	.302	.227	.241
Global bias	-.003	.002	-.190
Model 14			
Constant	-3.949	1.638	
SQ	.113	.042	.489
Raven score	.274	.227	.219

Model 15			
Constant	-2.806	1.351	
SQ	.129	.040	.560

Appendix G. CTF Challenges

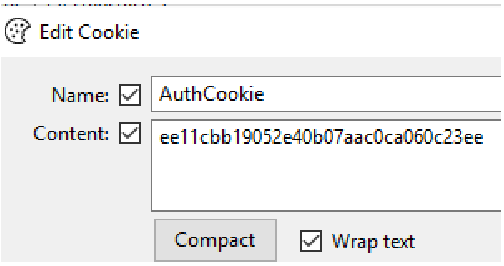
1. COOKIE 1 (category cookies)

In the Abertay Hacklab forum (http://10.0.0.201/forum), someone has half-baked the cookies. You have a user name of "user" and a password of "password". You must log in as "Gordon "to get the flag.

1. Go to *http://10.0.0.201/forum*

2. Login using the credential *user* and *password*

3. Use a tool to examine cookies, for example *cookie manager* Firefox add-in.

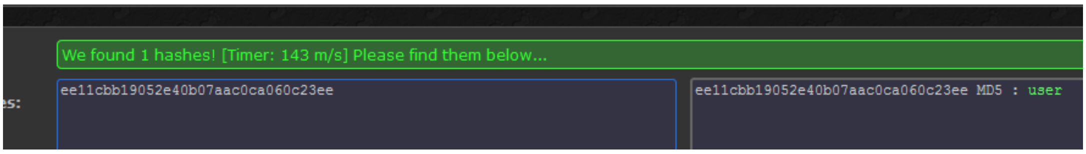


4. Understand by the length of the cookie (32 characters) that is a MD5 hashed.

5. Decrypt cookie

The cookie is MD5 hashed, which means that it has to be decrypted using a tool such as www.hashkiller.co.uk

6. Understand that the cookie is an MD5 of the username *(user)*



7. Apply deductive reasoning to understand that in order to login as GORDON, there is a need to do the reverse – i.e. compute the MD5 hash of the string GORDON using tools such as www.miraclesalad.com/webtools/md5.php

8. Once the MD5 hash for GORDON is obtained, use cookie editor to change the hash for *user* with the hash for *GORDON*

9. Use the cookie editor to change the user loggedin cookie with GORDON

10. Refresh the page

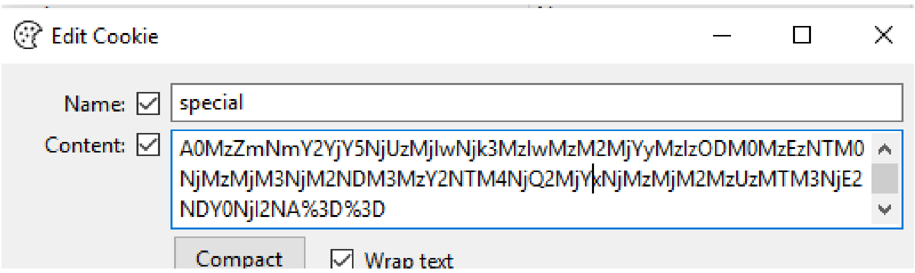
2. COOKIE 2 (category cookies)

In the Abertay Hacklab forum (http://10.0.0.201/forum), when you log on as "special" (password of "test") then you get a special cookie. Can you decipherex it to get the flag ==??

1. Go to *http://10.0.0.201/forum*

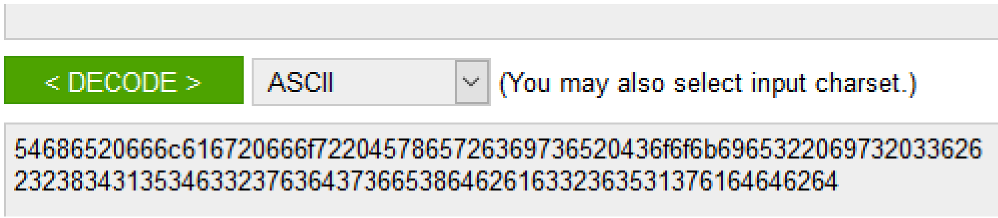
2. Login using *special* and *test* credentials

3. Use a tool to examine cookies, for example *cookie manager* Firefox add-in.



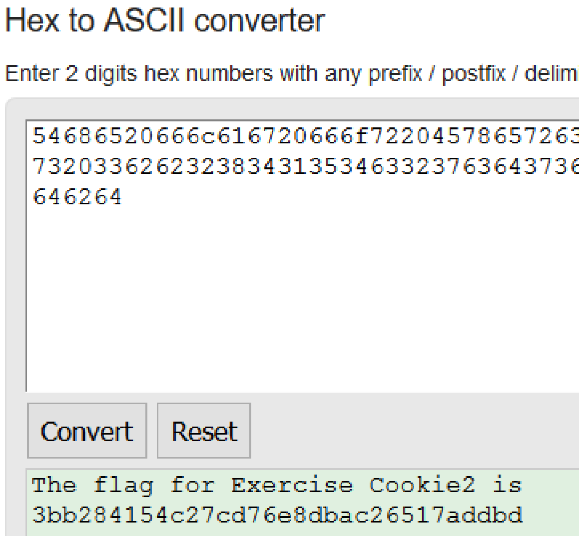
4. Understand that %3D are = signs and apply this knowledge to the current situation deducing that the cookie ends with ==. Understand that this means that the value is base 64 encoded.

5. Use a decoder tool to obtain a value (e.g. www.base64decode.org)



6. Use prior knowledge to understand that values (54,68,65 etc.) are within the HEX values for text (e.g. A=65 and so on)

5. Use a web application to convert HEX values to ASCII language (http://www.rapidtables.com/convert/number/hex-to-ascii.htm)



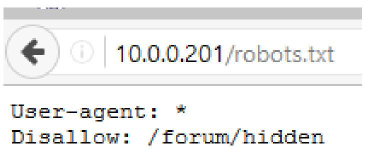
3. ENUMERATION1 (category enumeration)

In the Hacklab forum (http://10.0.0.201/forum), discover the obvious hidden file. Beware though, there are robots in the system.

1. Understand the clue that “*robots*” suggests that the answer lies in a robots.txt file.

2. Change the url typing 10.0.0.201/robots.txt and press enter

3. The file shows a hidden folder



4. Change the url typing 10.0.0.201/forum/hidden and press enter

5. A file is displayed in the folder, click on the file gives the key to solve the problem


```
Flag for Enumeration1 exercise = 4eebf705200f6e823ef85d95711c3a6c
```

4. ENUMERATION2 (category enumeration)

In the Hacklab forum (http://10.0.0.201/forum), try to "source" the next flag. It's there someplace.

1. Understand the clue hidden in the text above, that is there is the need to look in the source code of the page.

2. Retrieve previous knowledge that non application-critical pages are more likely to have left-over clues….e.g. *about* and *help*.

2. Try to type the url *http://10.0.0.201/forum/about.php or http://10.0.0.201/forum/help.php*

3. Right click on the page and click on *view source code*. In the about.php page there is the flag.

```
    </form>
<a href='logout.php'>Log Out</a><br/><a href='update_account.php'>Update Account</a><br/></td>
    <td valign="top">
    <!-- Flag for Exercise Enumeration4 = 966242192147c8f490bf262b04a7970e -->
<h3>About</h3>
```

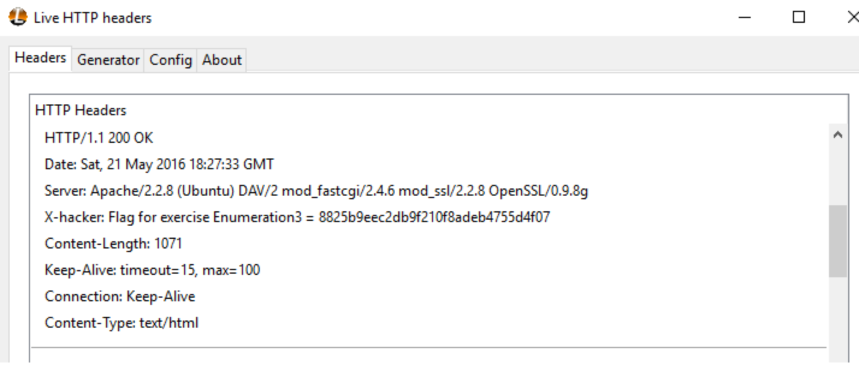
5. ENUMERATION3 (category enumeration)

Headers can give all sorts of information. Even flags. Try to find one in the Hacklab forum (http://10.0.0.201/forum).

1. Run Firefox plus adding in *LiveHTTP Headers* add-in

2. Try to browse different pages by changing the url in order to find in which one the flag is hidden

3. In the http://10.0.0.201/forum/index.php page there is find the X-Flag X-hacker.



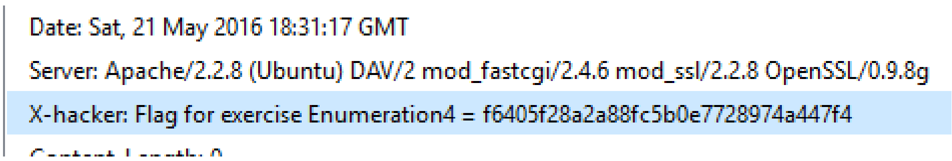
6. ENUMERATION4 (category enumeration)

Hmmmm. What' going on at the Hacklab forum http://10.0.0.201/forum/mystery.php !!

1. Type the url address *http://10.0.0.201/forum/mystery.php*. It gives a blank page.

2. Right click in the page and click on view source. An empty page appears.

3. Understand that it is needed to run *LiveHTTP Headers* to solve the problem.



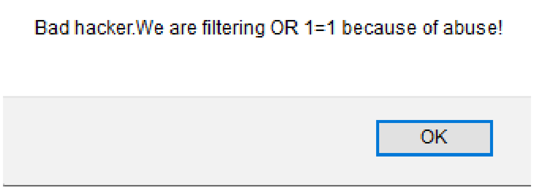
7. INJECTION1 (category injection)

In the Hacklab forum (http://10.0.0.201/forum), the first user in the database is test. Log in as test and you will reveal the flag.

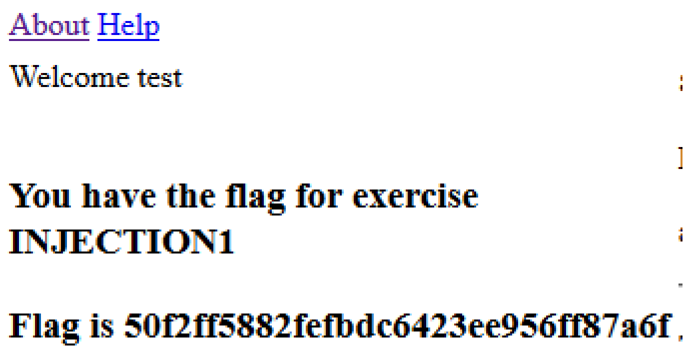
1. Go to *http://10.0.0.201/forum*

1. Log in with *'OR 1=1—*' and any password. Previous knowledge is needed to know that 'OR 1=1— ' is an attempt to make a query succeed no matter what.

2. It appears a message saying that the OR 1=1 has been filtered, which means that developers have taken into consideration the case in which an attacker would have tried to enter the website and have blocked the possibility to enter by using this solution.



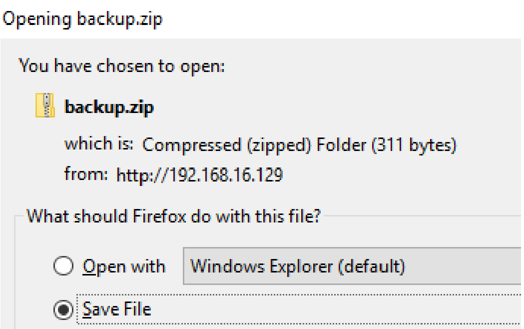
3. Try to alter to 'OR 2=2-- or 'OR 'a'='a'—or any other combination to login as the first user in the database (i.e. test).



8. ENUMERATION5 (category enumeration)

Back up to Abertay Hacklab Store (http://10.0.0.201/store) to see if you can find the flag.

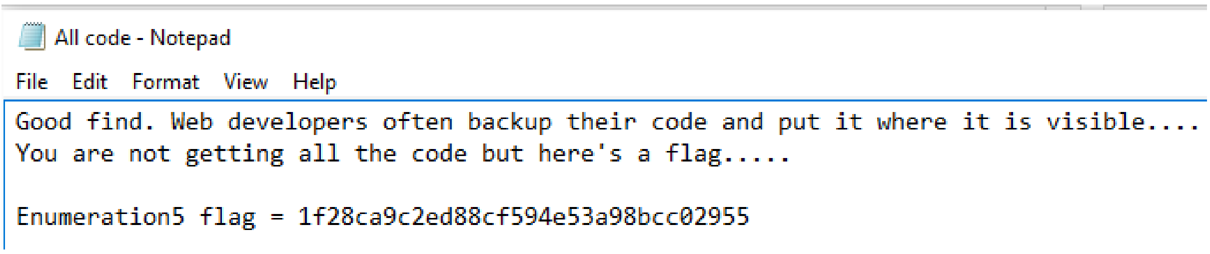
1. Read and understand the clue in the text. User have to browse to see if there is a backup folder or file (e.g. backup.zip)



2. Change the url with *http://10.0.0.201/store/backup.zip*

3. It will automatically show there is a folder to be opened.

4.Open the folder to discover a file called “all code” that contains the solution.


All code - Notepad

File Edit Format View Help

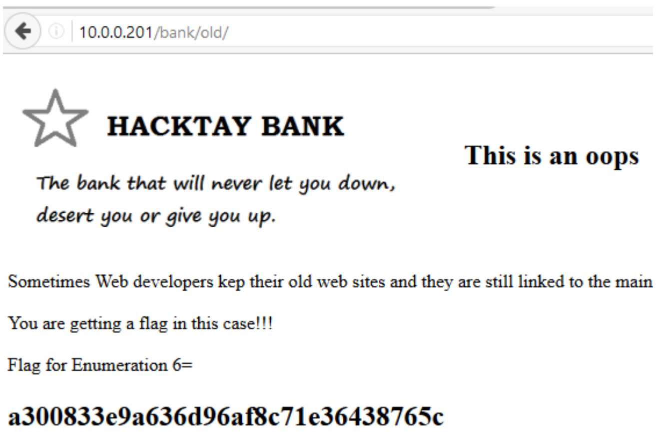
Good find. Web developers often backup their code and put it where it is visible....
You are not getting all the code but here's a flag.....

Enumeration5 flag = 1f28ca9c2ed88cf594e53a98bcc02955

9. ENUMERATION6 (category enumeration)

Sometimes old developers can leave all sorts of information that is visible to users if they know where to look. Even flags. Try to find one in the Hackbank ((http://10.0.0.201/bank).

1. Understand the information embedded in the text. The word “old” is a clue. The user has to browse to see if there is an old folder by changing the url with *http://10.0.0.201/bank/old*


10.0.0.201/bank/old/

HACKTAY BANK

The bank that will never let you down, desert you or give you up.

This is an oops

Sometimes Web developers kep their old web sites and they are still linked to the main

You are getting a flag in this case!!!

Flag for Enumeration 6=

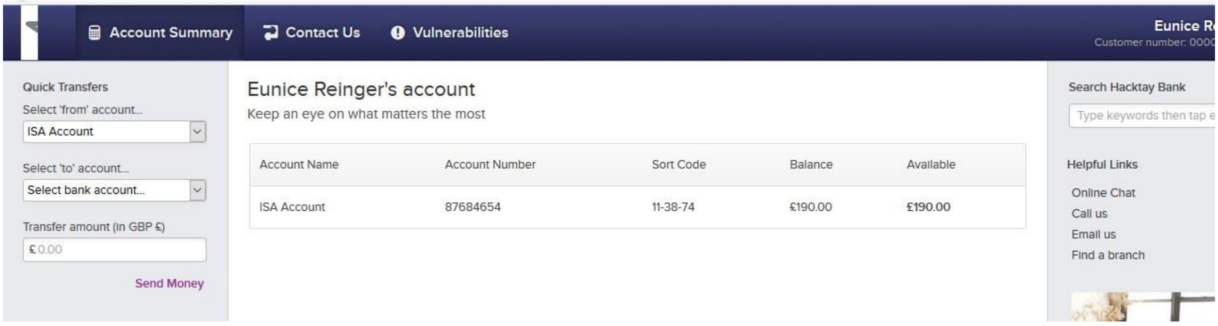
a300833e9a636d96af8c71e36438765c

10. COOKIE3 (category cookies)

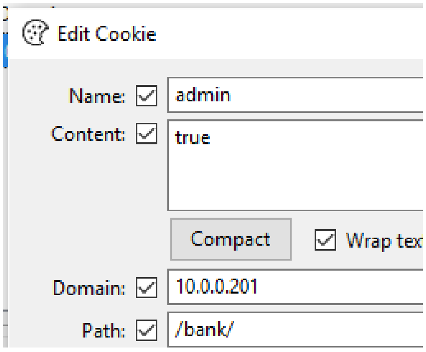
Web developers can often put in hidden ways of getting more functionality e.g. admin rights. Secret cookies is one way. Log in to Hacklab Bank (http://10.0.0.201/bank) as Eunice Reinger user '0000044444' with a password of 'youllnevergetme' then see if you can elevate yourself to admin.

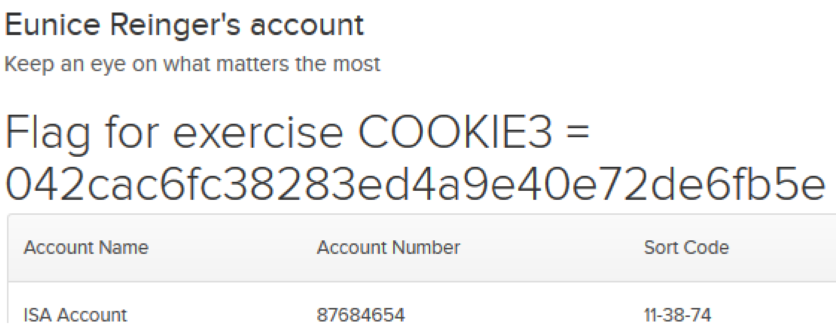
1. Type the url address *http://10.0.0.201/bank*

2. Log in with the provided username *0000044444* and password *youllnevergetme*



3. Use *cookie manager* to create a cookie called admin



1. Refresh the page
2. 

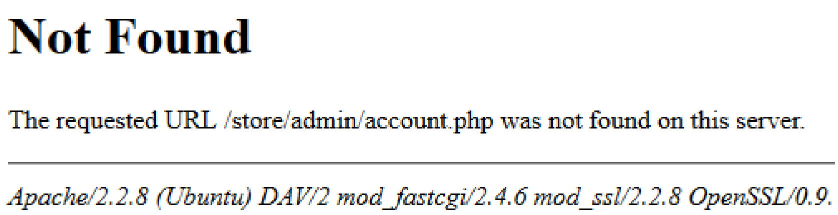
3.

11. INJECTION (category injection)

In the Abertay Hacklab Store (http://10.0.0.201/store), there is a hidden admin page (http://10.0.0.201/store/admin/admin.php) that can only be viewed by users with admin rights. Inject your way in to this page as the user Colin@hacklab.com to get the flag.

1. Type the url address *http://10.0.0.201/store/admin/admin.php*

2. The page gives an error.



3. User has to inject to get in. By previous knowledge the user knows that 'OR 1=1-- is an attempt to make a query succeed no matter what. The password can be whatever the user want.

4. The first user is Colin

5. Browse to the Url to solve the problem

12. ENUMERATION7 (category enumeration)

Directory traversal can reveal files and folders that hackers can leverage. In the Abertay Hacklab Store (http://10.0.0.201/store), the admin has left a hidden folder that contains a flag.

1. Go to http://10.0.0.201/store Traverse [20] to the folder

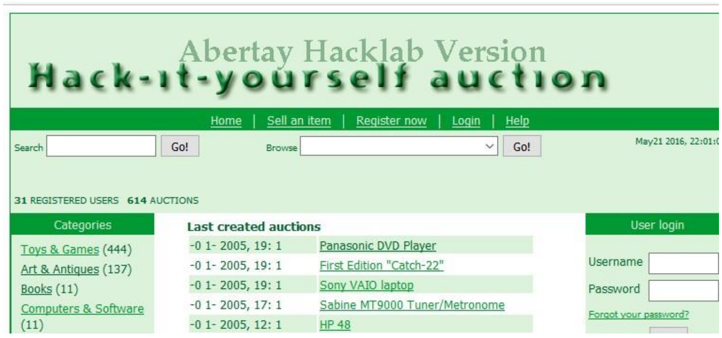
[20] Traversal" just means walking through (all or some) elements of a data structure

13. BASICS1 (category basics)

Log in to the Abertay Hacklab Auction site (http://10.0.0.201/phpauction)as user "hacklab", password "hacklab". Can you buy an item for $1.

1. Type the URL *http://10.0.0.201/phpauction*

2. Log in with the provided username *hacklab* and password *hacklab*

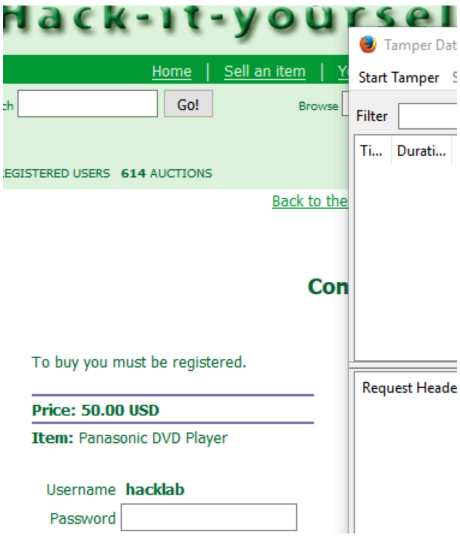


3. Pick one of the items displayed in the database and double click on it.

4. Run *tamperdata* or a similar tool in Firefox.

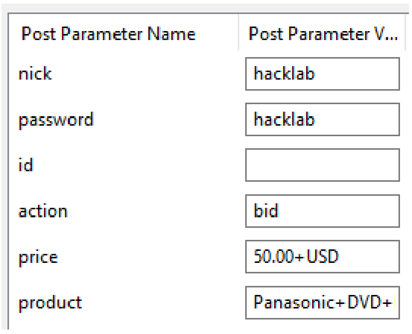
5. Start tampering[21]

[21] Tampering describes a malicious modification of products



6. Enter the password provided in the text

7. Tamper with the 50$ and change the value to 1$



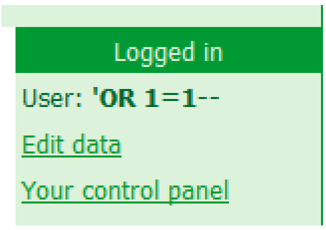
Post Parameter Name	Post Parameter V...
nick	hacklab
password	hacklab
id	
action	bid
price	50.00+USD
product	Panasonic+DVD+

14. INJECTION3 (category injection)

The Abertay Hacklab Auction site (http://10.0.0.201/phpauction) has a lot of vulnerabilities. The flag is Mark Shahaf's credit card number . Make sure you inject your way in then have a look around…

1. Type the URL *http://10.0.0.201/phpauction*

2. Inject to the system using “OR 1=1--“



3. Go to “your control panel” to see all the transactions and find the solution to the problem

User's control panel

User: 'OR 1=1--

Name	Credit Card	Email	Tel
Assaf Three	25803333333333	testme4@test.com	1234567

Name	Credit Card	Email
Mark Shahaf	Flag Injection 3 b170605fec9f4602c1df59f14d838a	testme4@test.com

Name	Credit Card	Email	Tel
Shahaf Mark	3333-455454-65656	testme4@test.com	1234567

Name	Credit Card	Email	Tel

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