The things you do: Implicit person models guide online action observation.

by

Kimberley Caroline Schenke

School of Psychology

Faculty of Health and Human Sciences

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At no time during the registration for the degree of Doctor of Philosophy has the author been registered for any other University award without prior agreement of the Graduate Committee.

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Publications

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Joyce, K., Schenke, K., Bayliss, A., & Bach, P. (2015). Looking ahead: Anticipatory cueing of attention to objects others will look at. *Cognitive Neuroscience*, July, p1-8. DOI: 10.1080/17588928.2015.1053443

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Abstract

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Kimberley Caroline Schenke

Social perception is dynamic and ambiguous. Whilst previous research favoured bottom-up views where observed actions are matched to higher level (or motor) representations, recent accounts suggest top-down processes where prior knowledge guides perception of others' actions, in a predictive manner. This thesis investigated how person-specific models of others' typical behaviour in different situations are reactivated when they are re-encountered and predict their actions, using strictly controlled computer-based action identification tasks, event-related potentials (ERPs), as well as recording participants' actions via motion tracking (using the Microsoft Kinect Sensor). The findings provided evidence that knowledge about seen actor's typical behaviour is used in action observation. It was found, first, that actions are identified faster when performed by an actor that typically performed these actions compared to another actor who only performed them rarely (Chapters Two and Three). These effects were specific to meaningful actions with objects, not withdrawals from them, and went along with action-related ERP responses (oERN, observer related error negativity). Moreover, they occurred despite current actor identity not being relevant to the task, and were largely independent of the participants' ability to report the individual's behaviour. Second, the findings suggested that these predictive person models are embodied such that they influenced the observers own motor systems, even when the relevant actors were not seen acting (Chapter Four). Finally, evidence for theses person-models were found when naturalistic responding was required when participants had to use their feet to 'block' an incoming ball (measured by the Microsoft Kinect Sensor), where they made earlier and more pronounced movements when the observed actor behaved according to their usual action patterns (Chapter Five). The

findings are discussed with respect to recent predictive coding theories of social perception, and a new model is proposed that integrates the findings.

Table of contents

List of figures

List of tables

Chapter One – Using person-specific models to make social action predictions

Deciphering social interactions

Being able to understand the actions of others is integral to social interactions. People rely on their ability to make sense of others' actions to decide whether they want to cooperate or compete (e.g., Sartori, Becchio, & Castiello, 2011), to plan their own actions when interacting with them (Sebanz & Knoblich, 2009), and to learn new skills from observation (i.e., Paulus, van Dam, Hunnius, Lindemann, & Bekkering, 2011). Originally, this capacity may have developed as part of an adaptive evolutionary behaviour to distinguish threatening behaviour (that should be avoided for survival) from friendly or cooperative behaviour, where approach may be beneficial. Nowadays, where thousands of humans live within a small area, understanding others may be more instrumental in terms of being liked by others, or gaining a higher social standing.

Yet, social interactions are extremely dynamic. People must constantly decipher not just the behaviours of interaction partners, but also the intentions and attitudes driving these behaviours, which are not directly observable and, in some cases, may be deliberately concealed. Additionally, social stimuli are highly ambiguous: the same action can have different meanings depending on the situation. For example, one might interpret a frown from a friend as feeling negatively about, or simply as assessing, the information we have just given them. Similarly, one could interpret a smile either as a positive reaction, or a mocking aside, to the conversation. This ambiguity is not well tolerated in those with social anxiety disorder (Kuckertz, Strege, & Amir, 2016), and may be part of the underlying causes of the social deficits typically seen in individuals with autism spectrum disorder (ASD) and schizophrenia (Koster-Hale & Saxe, 2013; Pellicano &

Burr, 2012). Therefore, an important question is how people resolve these ambiguities, and why making sense of others tends to come so naturally to people.

The bottom-up approach to social perception; monkey see, monkey do.

Mankind's remarkable ability to fluently and effortlessly make sense of others' behaviour is typically conceptualised as a bottom-up process (di Pellegrino, Fadiga, Fogassi, Gallese, & Rizzolatti, 1992; Gallese & Sinigaglia, 2010; Iacoboni, 2009a; Rizzolatti & Craighero, 2004). The assumption is that incoming sensory stimulation about observed actions is analysed in higher sensory areas, and matched to one's prior knowledge about them. The dominant view is that this knowledge is primarily encoded motorically. Observed actions are assumed to be mapped onto one's prior experience with the same action, such that the associated interoceptive and mental states can be re-activated. For example, seeing someone move their arm in a certain way (e.g., towards a cup) would be 'mapped' onto one's own motor system, which allows us to derive their internal states in terms of the goals, emotions and beliefs driving the behaviour (Becchio et al., 2012; Becchio, Sartori, Bulgheroni, & Castiello, 2008; Giacomo Rizzolatti & Craighero, 2004; Sartori et al., 2011; Sartori, Bucchioni, & Castiello, 2012).

A large body of evidence has confirmed such an activation of "internal" aspects of observed actions. For example, many studies have shown that observing an action facilitates the execution of that same action (but inhibits the execution of a different action), implying an activation of the motor commands that would generate it (Brass, Bekkering, Wohlschlager, & Prinz, 2000; Kilner, Paulignan, & Blakemore, 2003), or at least the activation of the same effector (Bach & Tipper, 2007; Heyes & Leighton, 2007). These effects can be specific to certain parameters of actions only. For example, in a task where participants simply had to use their thumb and index finger to match the size of an object, the aperture between thumb and finger increased after observing power grasps, and decreased after observing precision grasps (Gianelli, Dalla Volta, Barbieri, & Gentilucci, 2008). It can even be found in real-life face to face interactions. For example, people have a tendency to "mimic" others' behaviours such that if one person touches their face, the interaction partner may have a tendency to do the same (Chartrand & Bargh, 1999). Similarly, if one interaction partner uses certain words, the other may utilise the same specific terminology (see Lakin, Valerie, Cheng, & Chartrand, 2003) and syntactic constructions ("syntactic priming", Branigan, Pickering, & Cleland, 1999). Even young infants show such mimicry behaviour (Meltzoff & Moore, 1994). Mimicry has been found to be beneficial in terms of enhancing social cohesion (e.g., Chartrand & Bargh, 1999), communicating similarity (e.g., Gueguen & Martin, 2009), increasing synchrony between interaction partners (Sebanz, Bekkering, & Knoblich, 2006), and enhancing the understanding of a situation by activating the same motor systems within the observer (Becchio et al., 2012; Becchio, Sartori, Bulgheroni, & Castiello, 2008; Giacomo Rizzolatti & Craighero, 2004; Sartori et al., 2011; Sartori, Bucchioni, & Castiello, 2012), or as a communicative aid (e.g., demonstrating an understanding that a friend is in pain; Bavelas, Black, Lemery, & Mullett, 1986).

On a neuronal level, motoric bottom-up matching views have received support from the discovery of 'mirror' neurons in monkeys, which fire both when the monkey performs an action and when it merely observes that same action whilst being completely passive (e.g., di Pellegrino et al., 1992; Gallese, Fadiga, Fogassi, & Rizzolatti, 1996). Mirror neurons may therefore provide the neuronal mechanism that matches observed actions to one's own internal action representations (Rizzolatti & Craighero, 2004). Whilst it is (ethically) more difficult to perform single cell recordings in humans, a few studies have demonstrated direct evidence of mirror neurons in humans (Keysers & Gazzola, 2010; Mukamel, Ekstrom, Kaplan, Iacoboni, & Fried, 2010). However, the vast majority of research testing mirror neurons in humans uses more indirect measures such as fMRI (Buccino et al., 2001; Chong, Cunnington, Williams, Kanwisher, & Mattingley, 2008; Newman-Norlund, van Schie, van Zuijlen, & Bekkering, 2007) and MEG (Kessler, Gross, Schmitz, & Schnitzler, 2006; Kessler, Biermann-Ruben, et al., 2006), and therefore only suggests general brain structures in premotor and inferoparietal cortex being activated during both action observation and execution. Recently though there has been converging evidence from new fMRI imaging techniques such as multivoxel pattern classification or repetition suppression that common activations for action execution and observation may indeed emerge from the same underlying neuronal populations (Norman, Polyn, Detre, & Haxby, 2006; Oosterhof, Tipper, & Downing, 2012; Oosterhof, Wiggett, Diedrichsen, Tipper, & Downing, 2010).

The notion that mirror neuron activation reflects action understanding has received support from studies both in monkeys and humans. In humans, activation in mirror-related regions in the parietal and premotor cortex has been shown to occur more strongly for biological motion (e.g., Buccino, Binkofski, & Riggio, 2004; Kilner et al., 2003), and for actions within the motor repertoire of the observer (Calvo-Merino, Glaser, Grèzes, Passingham, & Haggard, 2005; Calvo-Merino, Grèzes, Glaser, Passingham, & Haggard, 2006). In monkeys, their firing is restricted to goal-directed actions, not the same kinematics when pantomimed without an object, and they fire even when the entire action is not performed within view, but becomes occluded half way through (Umiltà et al., 2001; for a review see Fabbri-Destro & Rizzolatti, 2008). This suggests that, once identified, the action is understood to the extent that it may be mentally completed by the motor system (e.g., Sparenberg, Springer & Prinz, 2012; Wilson & Knoblich, 2005).

Such ‘embodiment effects’ of action observation are not limited to performing actions. For example, people also automatically mirror others’ shifts in eye gaze (Frischen, Bayliss, & Tipper, 2007), and mirror neurons for eye gaze have recently been discovered in monkeys (Maranesi et al., 2013). Similarly, cortical representations of seeing and feeling pain overlap to a large extent (Morrison, Lloyd, di Pellegrino, & Roberts, 2004), and seeing others’ being touched can lead to illusory sensations of touch on one’s own body (Bach, Fenton-Adams, & Tipper, 2014; Blakemore & C. Frith, 2005; Morrison, Tipper, Fenton-Adams, & Bach, 2013). Even restrictions to others’ movements seem to be reflected in one’s own motor responses. Observing a ‘restrained’ finger and having to move that same finger oneself leads to slower response times, and decreased activation of motor-related ERP components (Liepelt et al., 2009).

Whilst a large number of studies provide converging evidence for motor system activation during action observation, notably fewer directly show that this motor activation contributes to how the action is understood. However, there are now several studies showing that the link between motor system activation and action perception is bidirectional; action observation affects own motor behaviour, and own motor behaviour affects observation of others’ actions (for a review, see Avenanti, Candidi, & Urgesi, 2013; for a critical discussion, see Meier, Schnall, Schwarz, & Bargh, 2012). For example, increased fluency of one’s own responses during action observation influenced perception of the actions of others, such that the actor appeared more skilled in the seen action (Bach & Tipper, 2007). Similarly, the predictability of an occluded action was enhanced if participants had previously used that body part (Springer, Brandstädter, & Prinz, 2013). Casile and Giese (2006) blindfolded participants and trained them in novel movements. When later asked to visually recognise these actions, performance positively correlated with how accurately they were able to execute the action during the learning phase (for similar findings see Reithler, van Mier, Peters, & Goebel, 2007; Thornton & Knoblich, 2006). Moreover, several studies (reviewed in Avenanti et al., 2013) now show that lesions to the parietal and premotor network – either real or virtual when induced via transcranial magnetic stimulation (TMS) – disrupt action perception, suggesting a causal role for these "mirror" regions in action understanding (Bach, Nicholson, & Hudson, 2014; Caramazza, Anzellotti, Strnad, & Lingnau, 2014).

Together, these data provide converging evidence that the motor system is activated during action observation, and that this activation plays a causal role in the understanding process. These ideas of bottom-up activation of the motoric meaning of others' actions have been incredibly influential. For example, mirror neurons are thought to be involved in several important social processes including empathy, theory of mind, mimicry and language understanding (for a review see Oberman & Ramachandran, 2007). However, more recently, doubts have been raised about whether these motoric bottom-up accounts can fully account for all the reported phenomena in the literature (e.g., Csibra, 2008; Kilner, Friston & C.D., Frith, 2007), and action understanding in general.

Cracks in the mirror

Even for low-level vision, where the challenge of deriving meaning from the stimulus is computationally much simpler, there is increasing evidence to suggest that bottom-up models cannot fully account for it. For example, bottom-up mechanisms alone cannot even reliably extract simple image features from natural images (see Yuille & Kersten, 2006 for a review). This is because different images on the retina can be created depending on aspects such as the viewpoint, light, shading, etc., which can make the same object look different, or different objects look the same on the retina. To then consider the complex nature of how objects interact in the real world (overlapping in location, partially occluding each other, etc.), it is unsurprising that recovering the generator of these images is incredible difficult.

In social perception, these problems are further complicated because the reasons for others' behaviour emerge from hidden states that influence behaviour non-deterministically. Moreover, similar to object perception, there is not a one-to-one mapping of actions to goals or internal states (Bach, Knoblich, Gunter, Friederici, & Prinz, 2005; Kilner et al., 2007): the same motor behaviour can serve different goals in different contexts e.g., inserting a letter into a letter box and inserting a bank card into an ATM. Additionally, different motor behaviours can achieve the same goals. Thus, an action's meaning, and the most likely intention driving it, is often determined by contextual cues (Press, Heyes, & Kilner, 2011), such as knowledge of the person and nearby objects.

There are various other reasons to be sceptical of bottom-up motoric matching accounts to reliably create "understanding" of observed actions. For example, not all movements that can be understood can be mapped onto our motor systems. There are actions that we ourselves cannot perform both within our species (e.g., a complex ballet movement) and within other species (e.g., a bird flying), yet we still readily attribute goals to these actions (Buccino et al., 2004).

Conversely, merely being able to perform an action does not necessarily enable understanding without specific knowledge of the goal (Hickok, 2013). For example, people do not just grasp an apple to eat it; sometimes it is simply to move it from the grocery bag to the table, or to pass it to a friend. Thus, seeing someone grasping an apple does not lead to any further understanding unless further information about the goal is known. This is especially true when social intentions are relevant. Someone could perform the exact same action but for very different reasons, which may not be clear to an observer who does not have access to their internal states. Jacob and Jeannerod (2005, p.23) use the example of Dr Jekyll and Mr Hyde whereby both grasp a scalpel and make incisions into patients, but one performs the behaviour to operate to save the patient, and the other performs the behaviour for the pleasure of seeing another in pain. An observer would not know these ‘hidden’ intentions simply by motorically re-performing the actions (which look identical).

Next to these theoretical arguments, there are various findings that have cast doubt on simple bottom-up motoric matching mechanisms as being key for social understanding. Foremost among them are demonstrations that motor activation during action observation reflects the (inferred) goal of the observed action, rather than the observed action itself. For example, Liepelt, Von Cramon, and Brass (2008) demonstrated that an observer’s motor system responds to the goal of an actor rather than to what was actually observed. Participants saw a finger trying to lift up, but being held down by a clamp. Motoric activation was found for the goal (finger lifting) not the observation (the finger restraint by the clamp). Similarly, participant responses are influenced by their action expectations for known actors (e.g., kicking for Wayne Rooney, tennis for Greg Rusedski; Bach & Tipper, 2006; Tipper & Bach, 2011) and objects (Bach, Bayliss, & Tipper, 2011; Bach et al., 2005; van Elk, van Schie, & Bekkering, 2009). This is not just apparent in adults, but also in children (e.g., Southgate, Johnson, El Karoui, & Csibra, 2010; Southgate, Johnson, Osborne, & Csibra, 2009). For example, infants were shown a grasping action, which elicited motor activation in their brain, but this activation was only found once anticipation of that action was possible. This suggests that the motor activation was not a direct result of observing the action, but was primarily driven by the action they *anticipated* seeing. Finally, whilst mirror neurons were previously thought to be a bottom-up motor matching mechanism, even these neurons have now been shown to fire for expected rather than observed actions (Maranesi, Livi, Fogassi, Rizzolatti, & Bonini, 2014; Umiltà et al., 2001). Such evidence is increasingly guiding researchers towards the notion that action understanding (and social perception) cannot purely be a bottom-up process, but must also have some top-down involvement (Bach, Nicholson, et al., 2014; Csibra, 2008; Kilner et al., 2007).

Flipping the mirror: social perception based on predictions

Top-down models of perception seek to solve the computational problems in perception – social and non-social - described above (Hosoya, Baccus, & Meister, 2005; Lee & Mumford, 2003) by theorising that high level inferences cascade to lower level sensory areas to provide predictions which aid perception (Bubic, von Cramon, & Schubotz, 2010; A. Clark, 2013; den Ouden, P. Kok, & de Lange, 2012; Friston & Kiebel, 2009). These frameworks hypothesise that (1) the brain is constantly making predictions, (2) based on prior knowledge, and (3) that these predictions propagate throughout the hierarchy to lower-level perceptual structures, and (4) act as a 'best guess' of what is perceived, which is continually updated as events unfold. When events mismatch expectation, prediction errors (5) propagate back up the system and the events are either explained away by adding additional guesses, or the best guess is revised to better reflect reality.

There is ample evidence for top-down influences on perception. Anecdotally, this has been seen in the mainstream media where some artists are thought to have ‘hidden’ messages in their songs that can be heard when playing the song backwards. Those hearing the ‘noise’ without any knowledge of what is alleged to be there are typically unable to decipher any lyrics, but those told the alleged lyrics ahead of time often report hearing them. This top-down influence on perception has also been shown in more lab-based experiments. For example, when listening to distorted speech, participants learn to decipher it over the course of the experiment using top-down lexical feedback (Davis, Johnsrude, Hervais-Adelman, Taylor, & McGettigan, 2005). What was previously unintelligible noise, can now be split into words and sentences.

Such top-down influence is also evident in visual processing. For example, one shot learning studies show how, after people have identified a certain object or pattern in noisy stimuli once, they cannot ‘un-see’ it (for a recent account see Ishikawa & Mogi, 2011). Top-down accounts also explain how surrounding illumination can be ‘explained away’ to enable perception of the ‘true’ colour of a surface (Bloj, Kersten, & Hurlbert, 1999). This has recently been seen for objects too in relation to the ‘blue dress illusion’; where the same photograph of a dress was perceived to be blue/black by some observers and white/gold by others (see Chetverikov & Ivanchei, 2016). Top-down accounts can also explain perception of object properties (e.g., whether an object is perceived to be concave or convex; Adams, Graf, & Ernst, 2004), and it has been argued that the switch between bi-stable figures could reflect the test of an alternative top-down hypothesis (Hohwy, Roepstorff, & Friston, 2008).

On a neuronal level, research has shown that prior top-down knowledge influences perception as early as 50-150ms (see Gamond et al., 2011), and that expectations influence processing at early stages of the cortical hierarchy for both visual processing (e.g., Alink, Schwiedrzik, Kohler, Singer, & Muckli, 2010; den Ouden, Friston, Daw, McIntosh, & Stephan, 2009; P. Kok, Jehee, & de Lange, 2012), and auditory processing (Todorovic, van Ede, Maris, & de Lange, 2011). For example, in the latter study, participants listened to auditory blocks with either expected or unexpected tone repetitions. There was evidence of a greater repetition suppression (i.e., neuronal attenuation the second time a stimulus is presented) in the auditory cortex for expected compared to unexpected repetitions.

Inspired by predictive coding models, several theorists now consider social perception to be similarly predictive in nature. As aforementioned, when first discovered mirror neurons were thought to implement a bottom-up mechanism, matching kinematic input to motor knowledge and thereby to the associated higher level goals. Csibra (2008; for a similar model see Kilner et al., 2007) now argues that mirror neurons might instead have a top-down function, predicting the most suitable action for the observed goal, by relying on the observer's knowledge about the action they would perform. Motor knowledge is, thus, not used to infer the goal of an observed action, but, instead, to find an action that would achieve a previously hypothesized goal, and to test whether this action corresponds to what is, indeed, perceived. Thus, in a similar way to having the top-down expectation that an object in the air will fall because of the laws of gravity, these neurons provide knowledge of the kinematics of what is required to achieve a goal. This "emulation" (Csibra, 2008) is compared to the event currently unfolding; corresponding visual input indicates that the goal has been correctly inferred, but a mismatch requires its re-assessment and a new resulting emulation.

Such predictive processes would not only allow people to check their understanding of others', but would be extremely useful for anticipating coordination of social interaction (e.g., Sebanz & Knoblich, 2009). Rapid decisions are needed for how to behave based on how an interaction partner is currently behaving, how they have behaved previously, and how they are likely to behave throughout the interaction. Predictions would enable fast and efficient categorization of events (e.g., Hoffmann & Sebald, 2005) by using available cues, or previously acquired knowledge, for example to judge whether a hand is being extended in greeting or threat. If a potential interaction partner smiles or has open/passive body language we may predict they are more likely to approach, or be more approachable, than a frowning individual who has closed/aggressive body language. Moreover, if we know that John is generally helpful and George is generally selfish, we would be more likely to approach John to help us with a problem. Thus, these predictions can help us to have more successful social interactions, and enable the rapid adaptation of behaviour to suit the current situation as events unfold.

Several pieces of research evidence are emerging to support this predictive view of social perception. For example, Flanagan and Johansson (2003) demonstrated similar predictive eye movements (i.e., looking at the object before the movement had been completed) both when the participants executed an action themselves, and when they merely watched an actor perform the same action. This demonstrates how, during action observation, participants were demonstrating their goal knowledge in much the same way as if they were actually performing the movement themselves. Similarly, Eshuis, Coventry, and Vulchanova (2009) showed that predictive eye movements are guided by inferred goals (from verbal statements), not kinematics, and several others have now confirmed that implied goals through eye gaze (Teufel, Fletcher, & Davis, 2010), matching of hand grips to target objects (Ambrosini et al., 2013; Ambrosini, Costantini, & Sinigaglia, 2011), and other cues allow people to guide gaze towards the goal even if the action is not yet completed.

Other evidence comes from studies demonstrating motoric involvement during action observation (neuronally e.g., di Pellegrino et al., 1992; for a review see Oosterhof, Tipper, & Downing, 2013; and behaviourally e.g., Bach, Peatfield, & Tipper, 2007; Fadiga, Fogassi & Rizzolatti, 1995; Naish, Houston-Price, Bremner, & Holmes, 2014). As reviewed above, these activations have recently been shown to be predictive, reflecting the actions that are expected, rather than those that are observed (Bach & Tipper, 2006; Bach et al., 2005; Bach, Nicholson, et al., 2014; Csibra, 2008; Kilner et al., 2007; Liepelt et al., 2008; Maranesi et al., 2014; Southgate et al., 2010, 2009; Tipper & Bach, 2011; Umilta et al., 2001; van Elk et al., 2009).

As hypothesised by predictive coding accounts, even low-level perception of observed action can be influenced by top-down information in the form of implied goals. For example, Kourtzi and Shiffrar (1999) presented participants with static images of the beginning and end of an action in an apparent motion paradigm, and found that participants tended to report seeing the intermediate stages of the action. This finding suggests that participants were representing these intermediate stages even though they were not actually shown. Earlier research by these authors demonstrated that such intermediate 'sightings' abide by biomechanical and physical constraints (i.e., when seeing a human acting, they only 'see' actions that are possible for a human to perform; Chatterjee, Freyd, & Shiffrar, 1996; Shiffrar & Freyd, 1990, 1993).

Similar evidence of top-down goals influencing perception has been provided more recently. For example, when participants were shown heads rotating towards the viewer, they perceived a greater rotation when the eye gaze appears to 'lead' the rotation (implying a goal for looking in the predicted direction) compared to a gaze that was 'lagging' (as though it wanted to look in the opposite direction; Hudson, Liu, & Jellema, 2009; see also Hudson & Jellema, 2011; Hudson, Nijboer, & Jellema, 2012). Whilst these findings could be due to visual biases caused by integrating head and gaze into one percept, more recent studies suggest evidence more towards perceptual biases reflecting top-down goal information (Hudson, Nicholson, Ellis, & Bach, 2016). Here, participants first heard an actor goal (“I’ll take it”, “I’ll leave it”), then they saw reaches toward, or withdrawals away from, objects, and reported the sudden disappearance point of the movements. The intent to ‘take’ the object led to an increased perception of a reach being near the object, and an intention to ‘leave’ led to an increased perception of a withdrawal being further away.

Together, these findings suggest that social perception has a predictive component, where abstract higher level information elicits predictions about what other people will do. However, most of the research to date has focused on the use of social cues to make predictions. For example, emotional expressions have been shown to influence behavioural predictions (a smile for approach, a frown for avoidance; R. B. Adams, Ambady, Macrae, & Kleck, 2006). Similarly, ‘enjoyment’ smiles predict trustworthiness and cooperative behaviours compared to ‘non-enjoyment’ smiles (Johnston, Miles, & Macrae, 2010). Action kinematics and how they match available tools and goal objects (e.g., a hammer is for hitting nails) have also been used as social cues in predictions (Bach et al., 2011; Bach, Nicholson, et al., 2014; Hunnius & Bekkering, 2010; Stapel, Hunnius, & Bekkering, 2012; Stapel, Hunnius, van Elk, & Bekkering, 2010; for a review see Bach, Nicholson et al., 2014). Even simply observing someone gazing at an object elicits similar activation as observing them grasping the object, suggesting that object-directed gaze creates actor intentions in the form of predictions about others’ behaviour (Pierno et al., 2006). What is often neglected, however, is that people may also make predictions from the knowledge they have about the acting individuals, recalling their previous encounters or the general knowledge they have about them.

Towards a person-specific approach

Humans have a remarkable ability to recognise other people, with evidence for dedicated cognitive and neuronal systems for identifying and storing knowledge about others (e.g., C. D. Frith & U. Frith, 2012; Quinn & Macrae, 2011; Tempini et al., 1998; Todorov, Gobbini, Evans, & Haxby, 2007). Such knowledge includes descriptive information that can be used to categorise others (e.g., sex, race, general appearance), as well as information about their behaviour, which may be represented in internal models of others (e.g., Barresi & Moore, 1996; Hassabis et al., 2013; Newen, 2015; Park, 1986; Yomogida, Sugiura, Akimoto, Miyauchi, & Kawashima, 2014; see Meltzoff & Moore, 1994 for an example in infant imitation). It has been argued that such models represent the specific "intentional relations" (Barresi & Moore, 1996) that describe others' behaviour towards objects (John typically eats chocolate), but also the mental states implied by these behaviours (John likes chocolate). If such internal models exist, then they may be re-activated automatically when the individual is re-encountered to inform predictions about their most likely behaviour, reflecting person-specific behaviour within the given situation (see also Smith & DeCoster, 1998). For example, we might learn that when in the lounge John likes to read a book, but George will watch television, and, thus, we would predict that John will reach out and grasp his book rather than the remote control, and vice versa for George.

This thesis aims to investigate the influence of such person-specific prior knowledge on predictions, in other words, how knowing how someone typically behaves in a given situation influences our predictions of how they will behave when we see them in a similar situation again. Establishing such an influence is crucial. As noted above, whilst predictive coding models of social perception assume that predictions emerge from high-level knowledge about the other person, the research to date is restricted to general predictions about others based on social cues, such as smiles, gaze, or action kinematics (R. B. Adams, Ambady, Macrae, & Kleck, 2006; Bach et al., 2011; Hudson et al., 2016; Hunnius & Bekkering, 2010; Johnston, Miles, & Macrae, 2010; Hudson, Nicholson, Simpson, Ellis, 2015; Pierno et al., 2006; Stapel, Hunnius, & Bekkering, 2012; Stapel, Hunnius, van Elk, & Bekkering, 2010). These experiments therefore do not specifically test the hypothesis of whether predictions, indeed, reflect higher-level person information (their goals, beliefs, etc.), or whether they solely reflect action-level knowledge, where certain cues (e.g., a smile) directly predict certain behaviours (approach), without drawing upon person information at all.

These hypothesised person-models must be able to cope with the stochastic rather than deterministic behaviour of humans. This is because we do not have access to the internal states, beliefs, and motivations of others (Zaki, 2013), unless they provide us with this information (but even then this may be deceptive), such that their behaviour can never fully be predicted from prior events. Furthermore, the same person's behaviours may change across situations (e.g., Bach et al., 2014; Barresi & Moore, 1996; Ham & Vonk, 2003; Lupfer, L.F. Clark, & Hutcherson, 1990; Todd, Molden, Ham, & Vonk, 2011). In personality psychology, it has been demonstrated that rather than stable traits describing behaviour, others' behaviour is better accounted for as an interaction of predisposition and situation: one person may be outgoing with one person but not with the other, and vice versa for someone else. Allowing for these situational dependencies has been shown to provide a more robust behavioural description (e.g., being shy at school, but extrovert at home rather than shy all the time; Mischel & Shoda, 1995). Indeed, Barresi and Moore (1996) theorise that this situation-dependency is captured by people's internal models about others, which describe the specific 'intentional relations' between people and different objects they could interact with.

Similarly, Newen (2015) suggests that there are two types of internal models – person and situation, which jointly determine understanding of others.

This importance of situation is highlighted by research on object-directed actions whereby objects indicate actor goals/intentions (see Bach, Nicholson et al., 2014 for a review). For example, evidence suggests that we only automatically compute reaches for actors within reaching distance of an object, showing such a situation dependency of action predictions (Ambrosini, Scorolli, Borghi, & Costantini, 2012). Thus, internal models need to integrate both person-knowledge (goals, intentions, etc.) and the current situational constraints because some situations will not be conducive to achieve a specific goal. For example, one can only show kindness and altruism if there is an option to do so such as helping a homeless person, donating to charity, or helping an old lady across the street with her shopping (e.g., Lupfer et al., 1990; Ham & Vonk, 2003; Todd et al., 2011; Bach et al., 2014). Indeed, adults only tend to imitate those actions that suit the situational constraints (Bach, Bayliss & Tipper, 2013). Thus, to more accurately predict behaviour one must be aware not just of knowledge about the individual and knowledge about the situational constraints, but also the ‘intentional relations’ that link the actor to the situation (Barresi & Moore, 1996). These internal person-models would be reactivated when that individual is re-encountered in a similar situation to enable predictions about their forthcoming actions. This would provide a powerful mechanism for social coordination and understanding, and a reference frame against which others’ behaviour can be judged (Stinson & Ickes, 1992; Hastie, 1984; Srull, Lichtenstein & Rothbart, 1985; Zaki, 2013; Barresi & Moore, 1996).

Despite these theoretical considerations, there is very little research directly testing whether such internal models of other people are used during action observation and allow one to predict their behaviour. Some studies have shown that people re-activate simple action knowledge about others when they see them. For example, we recently demonstrated how participants can (implicitly) ‘learn’ that one actor tends to look towards food objects, and the other tends to look towards drink objects, which then guides the participants’ own attention (Joyce, Schenke, Bayliss, & Bach, 2015). Similarly, Frischen and Tipper (2006) demonstrated gaze-cueing effects after a three minute delay suggesting a face’s prior gaze direction can be stored in memory and retrieved when a face is re-encountered. However, while these studies showed re-activation of person-related information, they did not show that it plays a functional role during action observation, biasing action identification towards the expected behaviour in a predictive manner.

Other studies have shown the embodied re-activation of others’ stereotypical behaviours, for example, the typical behaviours of black and white people (Dickter & Gyurovski, 2012), the body parts associated with famous athletes (Bach & Tipper, 2006; Tipper & Bach, 2011), or people’s last seen emotional expression (Halberstadt, Winkielman, Niedenthal, & Dalle, 2009). Further evidence of this stems from a mimicry study in infants. Meltzoff and Moore (1989, 1994) first demonstrated mimicry of tongue protrusions or mouth openings with young infants. Then, when presented with the same experimenter (this time with a neutral expression) a day later, the same infants were more likely to perform the behaviour again as though they had remembered that this experimenter had previously performed a tongue protrusion (or mouth opening behaviour).

Whilst such findings capture action knowledge about the individuals, they do not show that this information is used for predicting their behaviour. Moreover, research to date has not directly tested the situational-dependency of human action as described above, where others’ behave differently in different situations, depending on the available objects and their idiosyncratic preferences (Bach, Nicholson, et al., 2014; Barresi & Moore, 1996; Mischel & Shoda, 1995).

One area that has focused on testing the role of person-specific behaviour descriptions for judgment is classic research in social psychology. “Spontaneous trait inferences” show that traits can be rapidly attributed to agents (see Chen, Banerji, Moons, & Sherman, 2014), and how mere behaviour observation can elicit personality judgements (Vonk, 1994). For example, several studies have shown that people establish person-models from behavioural descriptions (Hastie, 1984; Srull, Lichtenstein, & Rothbart, 1985; Srull, 1983; Stinson & Ickes, 1992). However, these person-models have only been shown to influence relatively abstract “offline” judgment processes, such as subsequent reading times for behavioural descriptions (Belmore, 1987), and explicit judgments and memories of these target individuals (Heider et al., 2007; Sherman & D. L. Hamilton, 1994; Stangor & McMillan, 1992 for reviews see D. L. Hamilton & Sherman, 1996; Srull & Wyer, 1989; Stern, Marrs, Millar, & Cole, 1984; Wyer, 2013). The online use of these person-models during action observation, which is assumed in predictive coding models in social perception, has not been tested. This thesis will make a first step towards filling this gap.

Thesis overview

The current thesis aims to directly test that person-specific internal models are used in action observation to predict other peoples’ forthcoming action. It uses a combination of classic “behavioural” measures from experimental psychology and embodied cognition, as well as electroencephalography (EEG)/event-related potentials (ERPs), methods to capture more naturalistic behaviour using motion tracking (in a ball kicking task), and observer recording of mimicry in a face-to-face social interaction.

First, the experiments in Chapter Two test the proposal of person-specific models for action prediction by investigating whether the frequencies with which actors act towards or away from objects influences response times when their actions have to be identified, even though actor identity is completely task-irrelevant and participants are not explicitly aware of the individual’s different behavioural tendencies. If person-specific internal models are used in action identification, responses should be faster for actions that the actor more frequently performs, compared to an action that they perform more rarely. Importantly, the final experiment in Chapter Two also directly investigated online action predictions where participants had to report which action (an act towards or turn away) would happen next for the actor with a given object.

Second, Chapter Three tests whether the effects, indeed, reflect anticipation of action rather than mere stimulus and/or response learning, in two ways. First, by measuring ERPs, which also provides an investigation into the underlying neural components involved in the person-models, it tests whether unexpected actions of the individuals elicit EEG components associated with prediction errors in social perception (i.e., the observer-related mismatch negativity). Second, it investigates whether there is transfer from verbal statements about which behaviour the actors would like to do, to later action observation, which would suggest that action meaning rather than abstract perceptual cues are being encoded when people watch and identify others’ actions.

Third, Chapter Four, extends the proposal of person-models to consider both pre-existing knowledge about well-known individuals (not just information established within the experiment), and tests whether person-knowledge is measurable not in action identification, but as “embodied effects” during action observation, showing activation of one’s own motor system driven by the anticipated (but not observed) action. Here, based on a previously used experimental paradigm (Bach & Tipper, 2006; Tipper & Bach, 2011), famous tennis and football players are identified using either hand or foot responses. This tests whether having prior knowledge that someone is a football player primes or inhibits observer responses with a foot compared to a hand response, and whether this, again, depends on the situation in which they are encountered (in the athlete’s sporty environments or in neutral situations), even though this information is not required for the athlete-identification task.

Fourth, the use of person-models for action prediction is investigated in a more naturalistic environment whilst testing the potential use of a novel measurement tool – the Microsoft Kinect Sensor (Chapter Five) by removing artificial responses (keyboard presses) and, instead, monitoring more realistic movements. Here, participants observe actors kicking a ball towards them each with, unbeknownst to participants, different behavioural tendencies (one tended to kick towards the right, and the other towards the left). Participants respond by ‘blocking’ the ball by stepping left or right, tracked by the Microsoft Kinect Sensor.

Fifth, predictive person-models are investigated by adapting a mimicry paradigm (Chapter Six). Here, participants interact with two individuals, one of whom tends to perform one behaviour (face touching), and the other tends to perform a different one (foot tapping). These individuals are then encountered a second time, but this time they do not make the respective movements. This allows a test of whether participants continue making the movements associated with the two individuals, which, if found, would suggest that participants (implicitly) ‘learn’ that one person tends to be a foot tapper and the other a head toucher, and reactivate this when re-encountering them again, leading to predictive mimicry.

Finally, a general model is proposed which is discussed in light of both the research carried out in this thesis, and prior literature (Chapter Seven). Limitations and open questions are also discussed here.

Chapter Two - Implicit integration of object and actor information for behavioural prediction

The previous chapter highlighted the importance of predictions for dynamic social interactions, specifically noting the lack of research about the influence of prior knowledge about the acting individuals' behaviour. The current chapter develops a first paradigm to investigate how person-specific internal models for how our interaction partners tend to behave in specific situations guide action observation.

Prior work has shown that observers re-activate general action-related information about others, such as the body parts used in the sport of famous athletes (Bach & Tipper, 2006; Tipper & Bach, 2011), people's last emotional expressions, or the direction of their gaze (Frischen & Tipper, 2006; Halberstadt et al., 2009). However, for efficient prediction, such general knowledge about others – such as someone's last seen expression or the body part they use most – is not sufficient. Efficient internal models for behaviour prediction need to capture the situation dependency of people's behaviour (Bach et al., 2014; Barresi & Moore, 1996; Mischel & Shoda, 1995), for example, that John typically reaches for chocolate but ignores peanuts, whilst Claire shows the opposite pattern (Barresi & Moore, 1996). Predictive internal models must, therefore, store – and re-activate – action knowledge in both a person- and situation-specific manner, predicting a reach in one situation and a withdrawal in others.

The current studies used a simple action identification task to test whether such prior knowledge about an individual's most likely actions in a given situation is used during action observation, and biases action identification towards these predictions. The paradigm involved two actors (John, Claire) and two objects (computer, football), and participants merely had to identify (via a button press) whether the actor acted with the object or turned away from it. Unbeknownst to participants, the frequencies with which the two actors made these actions with the two objects varied. One actor (e.g., John) would typically (in 80% of cases) act with the ball and rarely (in 20% of cases) turn away from it. In contrast, he would typically turn away from the computer (in 80% of cases), and rarely interact with it. The other actor (Claire) showed the opposite pattern.

As both the identity of the current actor as well as the current situation was completely irrelevant for the participants' task of action identification, the automatic use of the actor's behavioural tendencies to predict their most likely forthcoming action in a given situation can be tested. If participants form internal models that describe the two individuals' behaviour in the two situations and use these models to make predictions about their forthcoming actions, then it should be reflected in their action identification times. Participants should be faster in identifying an action when it is typically carried out by the given actor, compared to the same action when carried out by the other actor. In the above example, participants should be faster when identifying kicking a football than typing at the computer for John, and vice versa for Claire, even though the overall action likelihoods – across individuals and situations – were exactly equivalent.

This paradigm, therefore, tests not only whether participants incidentally acquire internal models of how the individuals behave in the different circumstances, but, more importantly, whether these internal models are accessed, fluently and routinely, whenever these individuals are seen again, even though neither situation nor actor are task-relevant. Such data would go beyond prior research by showing that (1) observers represent behavioural tendencies in a person-specific manner as theorised by Barresi and Moore (1996), (2) which is routinely activated during re-encounters with these individuals, and (3) is utilized to predict and facilitate identification of forthcoming actions. Note (4) that in this task, there is no simple relationship between individuals and response-relevant actions (e.g., withdrawals vs. interactions). Instead, it captures the required situation dependency of other's actions, such that the expected actions in each trial depended on both the current actor and the situation they are in, such that one actor typically interacts with one object and turns away from the other, and vice versa for the other individual.

An important benefit of this design is that such complex interdependencies, where an event depends on the interaction of two factors, especially when task-irrelevant (as in the current case), are typically learned by participants in a largely implicit manner (see Ashby, Alfonso-Reese, Turken, & Waldron, 1998; Maddox & Ashby, 2004). For example, in causal/statistical learning in the non-social domain, second-order relationships between instances are implicitly 'learned' (as demonstrated by faster responses to stimuli in line with these relationships compared to violations of these rules), but are often not able to be explicitly verbalised (Shanks & Stjohn, 1994). Even if such knowledge can be verbalised, it is rarely diagnostic of prediction effects seen in the response time task (e.g., Batterink, Reber, Neville, & Paller, 2015; Shanks & Perruchet, 2002). Rather than implying that there are distinct implicit and explicit learning systems, such findings may demonstrate that acquired internal models about the causal relationships between events can be used in two ways. First, during the response time task, the predictions can speed up perceptual and motor processing of the predicted events, leading to response time benefits when events follow the established relationships. In contrast, participants can also attempt to extract information from their internal models to make explicit judgments. This attempt to reactivate the internal models in both situations may be imperfect and influenced by different individual differences, much like general memory, leading to the lack of clear relationships (e.g., Cleeremans & Destrebecqz, 2003; Jamieson & Mewhort, 2009; Shanks & Perruchet, 2002). Evidence supportive of this view shows that being able to report the underlying rules is enhanced when the same cues are used during encoding and retrieval, and if they equate to the same knowledge gained in the response time task (Shanks & Stjohn, 1994). Similar dissociations are seen in social psychology for explicit judgments about others (Hastie & Park, 1986; Tormala & Petty, 2001), which may also be showing this ad-hoc ‘reading’ of internal models such that judgements were not made during the task, but post-hoc by drawing conclusions based on simulation/imagining/memory from what was observed.

Experiment 1a establishes the basic paradigm, showing that participants access internal models of others’ likely behaviour in the given situation during action observation, even though actor and situation are task-irrelevant. Experiment 1b replicates this using a further direct measure of explicit awareness. Experiment 1c investigates the prediction effects when the behavioural tendencies of the actors are explicitly given to participants. Experiment 1d dissociates such explicit and implicit knowledge. Finally, Experiment 1e provides a more direct measure of action predictions based on this person-knowledge.[1]

Experiments 1a and 1b – prediction based on person-specific behaviour tendencies

Experiments 1a and b test whether action observation automatically draws upon internal models that describe an individual’s typical behaviour in different circumstances. In a simple action observation task, participants reported whether an actor acted towards or away from an object, while both the situational context (in front of a computer, in front of a football) and the identity of the actor (Claire, John) varied. Unbeknownst to participants, the two actors were differentially likely to perform each action in each situation, such that one actor would typically act towards one object and away from the

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[1] Note, Experiments 1a, b and d have recently been published in a peer-reviewed journal (see Appendix).

other, and the other actor would perform the opposite behaviours. It was hypothesized that actions would be identified more quickly when carried out by an individual that typically performs this action in this situation, compared to an individual that carries it out more rarely.

Such an effect of actor identity (and their prior behaviour) on action identification would show, first, that observers establish internal models of other's behavioural tendencies towards different objects. Second, and more importantly, because actor and object were completely task-irrelevant, they would show that these internal models are accessed automatically and used to make action predictions. Third, they would show that these predictions bias action identification towards the most likely actions of the individuals to facilitate their identification compared to other actions (which are, overall, equally frequent, but typically carried out by someone else).

Pilot testing established that participants typically remain unaware of the experimental manipulation (only 3.61% of participants explicitly detected the pattern), probably because both person and situation are task-irrelevant, and because the actors' behaviour depended on the interaction of situation and actor factors, which is harder to detect and verbalise than more straightforward contingencies (Ashby et al., 1998; Maddox & Ashby, 2004). This lack of explicit awareness was further investigated in Experiment 1a by testing, (1) in a funnel debrief, whether participants noticed any patterns in the stimuli, as well as (2) by testing for more tacit information by asking participants to rate which objects they thought the two individuals "liked" to interact with more.

Both questions measure potentially dissociable components of participants' explicit knowledge. Question one tests for spontaneous detection of the manipulation that could have guided strategic responses of participants. Question two tests whether participants could, in principle, access their internal person models, if effectively probed. The latter question therefore does not reflect explicit knowledge about the global co-variation patterns, but the generation of such knowledge at the time of probing, perhaps by bringing to mind remembered instances of the seen stimuli (Shanks & Stjohn, 1994). Both questions therefore allow us to investigate, first, whether any predictive effects during action observation depend on such explicit knowledge (via regression analyses), and, second, whether the implicitly formed internal models can be accessed retrospectively to make judgements about the individuals.

Experiment 1b replicated Experiment 1a, but now half the participants were asked the liking questions (as before) and the other half were asked how frequently they remembered that the actors had interacted with each object. In this way, the questions capture both components of person representations assumed by Barresi and Moore (1996), allowing us to test whether people can derive explicit knowledge both about which actions others typically carry out in different situations (frequency), and which mental states these behaviours imply (liking).

Method

Participants

Forty-two undergraduates from Plymouth University took part in Experiment 1a (31 females, 37 right handed, mean age = 20.40 years, SD = 3.71 years), and fifty-seven in Experiment 1b (49 females, 51 right handed, mean age = 20.39, SD = 5.56 years), in exchange for course credit. Sample sizes were determined with G-Power (Erdfelder, Faul, Lang, & Buchner, 2007) on pilot data from different participants (n = 42), which indicated that a sample size of at least 36 was required to reliably detect a main effect of Expectancy (dz = .625) with .95 power. Participants were excluded from further analysis if they detected the experimental manipulation (Experiment 1a, n = 3, Experiment 1b, n = 2), or made more than 10% errors (Experiment 1a, n = 2). All experiments within this thesis were approved by the faculty ethical committee prior to data collection, and all measures, manipulations and exclusions are reported. In this, and all further experiments in the thesis, all reported *p* values are two-tailed.

Materials and apparatus

The autism quotient scale (AQ; Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001) contained 50 questions to measure the presence of autism-like traits in neurotypical individuals. No correlations were found between these traits and any of the effects in the experiments so these data will not be discussed further.

The experiment proper was controlled by Presentation (Neurobehavioral systems, Inc; version 14.9, Build 07.19.11) using a Windows XP SP3 1280x1024 32 bit colour 17" display. The stimuli consisted of 16 different two-frame sequences, which first show a neutral image of one of the two actors (John, Claire) in one of the two situations (next to a computer, next to a football), for 500 ms. This image was identical for both actions that might follow (interact, turn away), and served as a prime for the activation of person- and situation-specific internal models. The second image then showed the actor either interacting with this object (typing on the computer, kicking the football) or turning away from it, either until the participant made a response or for 2000 ms. The two images were presented without an inter-stimulus interval, creating the impression of apparent motion (Wertheimer, 1912). Static images were used rather than video clips to enable the removal, via photo-editing, of all cues for context such that only the object and actor were influential, and to provide unambiguous onset times for the action judgments (the second image in the sequence). To reduce Simon-like response effects

(Simon, 1969), in one half of the sequences, the object was presented on the left of the individuals, and in the other half it was on the right (see Figure 2.1).

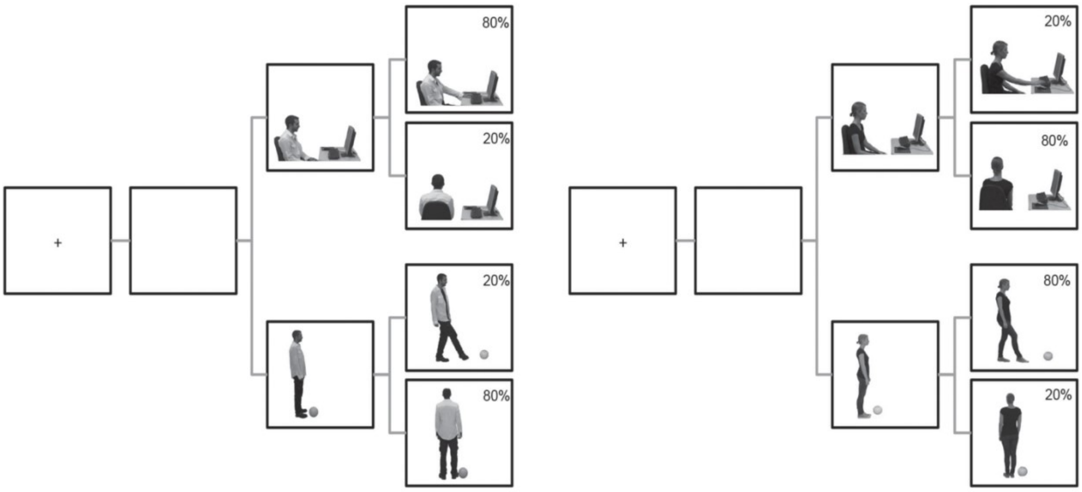

Figure 2.1. Schematic of the trial sequence.
Each trial started with a fixation cross (400 ms) and a brief blank screen. Each action started with an image showing one of the two individuals (left, John; right, Claire) in one of the two situations (at a computer, top; near a football, bottom). They then either interacted with the object or turned away from it, with one individual typically interacting with one object and turning away from the other, and vice versa for the other individual.

In the first exit questionnaire, participants in Experiment 1a, and half of participants in Experiment 1b, rated how much each actor liked each object on a Likert scale from -4 to 4 with no zero point (e.g., “How much do you think John liked the ball?”). The second half of participants in Experiment 1b rated how much each actor interacted with each object using the same scale.

The second exit questionnaire consisted of five questions identifying any evidence of explicit knowledge of the experimental manipulation that could guide strategic responses. They were first asked “How easy did you find the task of identifying whether the actors interacted with the object or turned away from the object?” by circling a number between 1 “really difficult” and 10 “really easy”. They were then asked: “Did you find one actor easier to identify than the other? If so please state which one.”, “Did you find one action easier to identify than the other? If so please state which one.", "Did you notice anything unusual about any of the actors or objects?", and "Did you notice any patterns in the stimuli?"

Procedure

Participants completed the AQ, before receiving written and verbal instructions for the computer task. When the experimenter was satisfied that the task was understood, participants completed the computer task, which contained 240 trials. Both actors (John, Claire) were shown equally often in each situation (in front of the computer or football), but the frequency of how often they interacted or turned away from each object varied. In 80% of the trials, the actors would perform their typical action, while in 20% they would perform their atypical action. Thus, for one participant, John would interact with the computer in 80% of cases and turn away from it in 20% of cases, while he would turn away from the football in 80% of cases and interact with it in 20% of cases. Claire would show the reverse contingences (interact with the football in 80%, and the computer in 20%, of the cases). These contingency mappings were counterbalanced across participants. The trials were presented in implicit blocks of 40 (four repetitions of the eight regular trials and one set of the oddball trials) to ensure an equal distribution of oddball trials across the experiment.

Each trial started with a blank screen followed by a fixation point in the centre of the screen (400 ms). After a blank screen of 400 to 800 ms (randomly chosen), one of the two-frame sequences was presented. Stimulus onset asynchronies (SOAs) between the first and the second frame of the action sequences was either 150 ms or 850 ms in Experiment 1a but, because no effects depended on SOA, in Experiment 1b the sequences followed each other with a fixed SOA of 500 ms. Participants pressed the

"UP" arrow key to identify that the actors were interacting with the objects (either typing or kicking), and the "DOWN" arrow key to identify that the actors were turning away from the objects. Participants were asked to respond as quickly and as accurately as possible. If they took longer than 2000 ms or responded incorrectly, an error message reminded them of the correct button assignment. After the experiment, participants completed the two exit questionnaires, were thanked and fully debriefed.

Trial exclusions

The first twelve trials of each experiment were considered training trials and excluded. Additionally, trials were excluded if they fell within any of the following criteria: (1) trials with RTs greater than 2000 ms (maximum duration of the response interval), (2) trials with anticipations (i.e., responses before the critical second frame), (3) trials where Presentation timing was uncertain (measurement uncertainties larger than 10 ms), and (4) trials with RTs over three standard deviations from this participants' condition mean. For the analysis of RTs, error trials were additionally excluded.

Results

Funnel debrief

The average overall ease of the task was perceived to be 7.79 (out of 10) for Experiment 1a, and 7.61 for Experiment 1b. The actors and actions/objects were equally salient with neither perceived as being easier to identify conclusively (see Table 2.1).

Table 2.1.

Data showing which actor and action/object participants rated as easier to identify for Experiments 1a and b

Character	Ex1a	Ex1b	Action	Ex1a	Ex1b
Claire	7	18	**Ball/kick**	10	19
John	9	11	**Computer/type**	17	24
Neither	23	22	**Interacting with an object**	0	1
			Turning from an object	2	3
			None	8	8

Participants' responses to the funnel debriefing were examined. Thirty-six participants (85.71%) for Experiment 1a, and forty-six participants (80.71%) for Experiment 1b, did not identify anything unusual about the stimuli. Thirty-two participants (76.19%) for Experiment 1a, and forty-three participants (75.44%) for Experiment 1b, did not identify any patterns in the stimuli, and the remaining participants suggested a series of unrelated points such as differences with the direction the characters faced, or differences with clothing. Some participants suggested they could identify when an acting towards vs. turn away action would happen, or the direction the characters would face (which is unlikely given that the order of the stimuli was randomly assigned). Three participants (7.14%) in Experiment 1a, and two participants (3.51%) in Experiment 1b, guessed the correct pattern and were removed from further analyses.

4.58% of trials were excluded in Experiment 1a based on the exclusion criteria, and 1.28% from Experiment 1b. The remaining data were analysed with a repeated measures ANOVA with the factors Observed Action (act with object, turn away from object) and Action Typicality (typical, oddball), separately for response times (RTs) and Error rates.

Response times

The analysis of Experiment 1a revealed no main effect of Observed Action, $F[1,36] = 2.233$, $p = .144$, $\eta\rho^2 = .058$, but a marginally significant main effect of Action Typicality, $F[1,36] = 3.140$, $p = .085$, $\eta\rho^2 = .080$, which was further qualified by an interaction between both factors, $F[1,36] = 6.378$, $p = .016$, $\eta\rho^2 = .151$. As can be seen in Figure 2.2, actions towards objects (kicking the football, typing on the computer) were identified more quickly when they were typical for the actor compared to when they were atypical, $t[36] = 3.330$, $p = .002$, *Cohen's* $d = .16$, but no such effect was found when actors turned from the objects, $t[36] = .518$, $p = .607$, $d = .04$.

The analysis of Experiment 1b fully replicated these findings. There was a marginally significant main effect of Observed Action, $F[1,51] = 3.070$, $p = .086$, $\eta\rho^2 = .057$, and the predicted effect of Action Typicality, $F[1,51] = 12.314$, $p = .001$, $\eta\rho^2 = .194$, with faster responses to actions that were typical of that actor compared to actions that were atypical. As in Experiment 1a, this effect was qualified by an interaction of both factors, $F[1,51]= 12.773$, $p = .001$, $\eta\rho^2 = .200$. Follow-up t-tests replicated that the RT advantage for typical relative to atypical actions was only present when the actors acted towards the objects, $t[51]= 4.620$, $p < .001$, $d = .29$, but not when they turned from them, $t[51] = .379$, $p = .707$, $d = .021$. Entering group (liking questions, frequency questions) as a between subjects factor did not reveal any further effects, all $F \leq 1.146$.

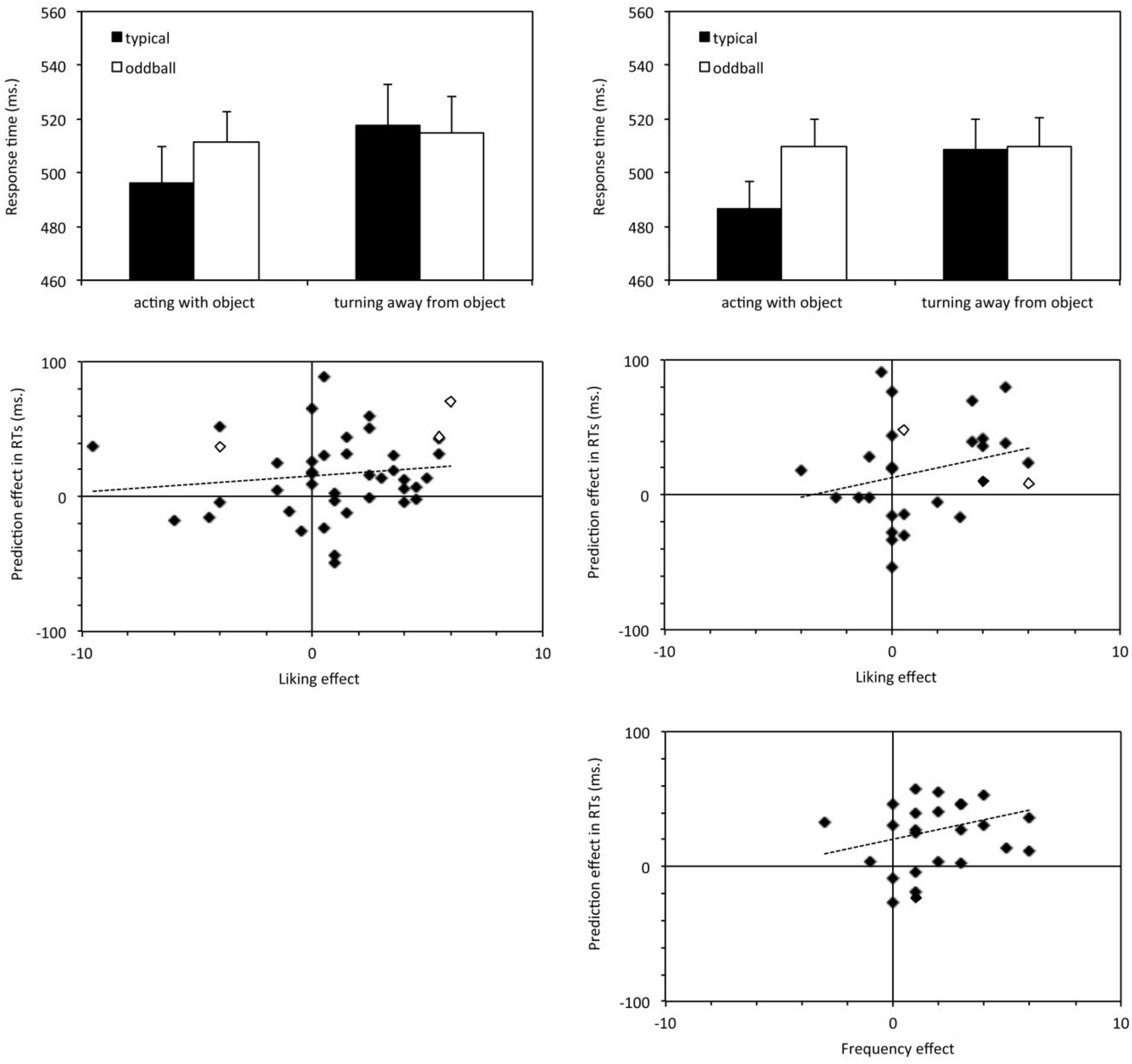

Figure 2.2. Response time and exit questionnaire data for Experiments 1a and 1b

Top panel: average response times in Experiment 1a (*left panels*) and 1b (*right panels*). In each panel, the left bars show identification of actions towards objects (typing on a computer, kicking the football), and the right bar shows actions away from objects. The black bars reflect actions expected of this individual in the given situation, and white bars show the action expected of the other individual. Error bars show the standard error of the mean.

Middle panel: correlation between prediction effects in the RTs for actions towards objects and the corresponding differences in perceived object liking and interaction frequency for individuals who either identified (*unfilled diamonds*) or did not identify (*filled diamonds*) the behavioural pattern in Experiment 1a (*left panels*) and 1b (*right panels*).

Bottom panel: correlation between prediction effects and differences in perceived action frequency.

Error rates

In Experiment 1b there was a main effect of Observed Action, *F*[1, 49] = 5.155, $p = .028$, $\eta\rho^2 = .095$, with more errors in the acting towards than turning away trials, but this was unrelated to the hypotheses. As seen in Tables 2.2 and 2.3, there were no other significant effects in either experiment (*F*s ≤ 2.124).

Table 2.2.

Mean and SD for the proportion of errors for Experiment 1a

	Likely for this actor – Mean (SD)	**Unlikely for this actor – Mean (SD)**
Acting towards objects	.04 (.03)	.05 (.05)
Turning away from objects	.05 (.05)	.04 (.04)

Table 2.3.

Mean and SD for the proportion of errors for Experiment 1b

	Likely for this actor – Mean (SD)	**Unlikely for this actor – Mean (SD)**
Acting towards objects	.03 (.02)	.04 (.04)
Turning away from objects	.04 (.04)	.03 (.04)

Liking and frequency ratings

Post experiment, participants rated how much the two actors liked the two objects (in Experiment 1a, and group 1 of Experiment 1b), or how much each actor had interacted with them (group 2 of Experiment 1b). Objects that were typically acted upon by the given actor were rated as more liked by this actor (Experiment 1a; *M* = 1.79, *SE* = 1.52, Experiment 1b; *M* = 1.74, *SE* = 1.21) than objects they typically turned away from (Experiment 1a; *M* = -0.17, *SE* = 1.89, Experiment 1b; *M* = 0.40, *SE* = 1.82), for Experiment 1a (*t*[36] = 3.818, $p = .001$, $d = 1.05$) and group 1 of Experiment 1b (*t*[26]=

2.498, *p* = .019, *d* = .80). Likewise, when the objects were typically acted upon they were rated as being interacted with more (*M* = 2.20, *SE* = 1.06) than when they were turned away from (*M* = 0.50, *SE* = 1.49) for group 2 of Experiment 1b (*t*[24] = 4.332, *p* < .001, *d* = 1.30).

Having established that participants could access some explicit information about the two actors' behaviour, a regression analysis then measured the relationship between apparent explicit awareness of actors' behaviours as seen in the liking and frequency ratings, and the response time effect for actions towards objects (the difference between likely and unlikely actions for the actor), for each of the three participant groups separately. Thus, those five participants that explicitly detected the contingencies between actors, objects and actions were also included in this analysis.

None of the three participant groups showed a significant correlation between awareness and liking/frequency ratings, (Experiment 1a, *r* = .187, *n* = 40, *p* = .248; Experiment 1b liking, *r* = .252, *n* = 28, *p* = .195; Experiment 1b frequency, *r* = .210, *n* = 26, *p* = .304). However, in each, the intercept was different from zero (Experiment 1a, *t* = 3.325, *p* = .002; Experiment 1b liking, *t* = 1.710, *p* = .099; Experiment 1b, frequency, *t* = 2.117, *p* = .045), indicating that even those with no apparent explicit awareness in the liking or frequency ratings still showed significant RT prediction effects. The same pattern is seen when the participants who detected the manipulation were excluded, with the exception that the intercept for the liking ratings in Experiment 1b now failed to reach marginal significance (*t* = 1.519, *p* = .142).

To attain enough power to detect weaker correlation effects, the data from all three subgroups were pooled. These analyses, indeed, revealed a marginally significant correlation between the post-experiment ratings and the response time effects (all participants, correlation; *r* = .186, *p* = .073; unaware participants only, correlation; *r*

= .181, *p* = .089). In addition, they confirmed the significant intercept (all participants, *t* = 4.957, *p* < .001, unaware participants only, *t* = 4.544, *p* < .001), indicating that even those who were unable to explicitly recall the actors' behaviour still showed reliable response time prediction effects.

Anticipations

Whilst the response time data revealed that participants anticipate the actors' typical actions across situations, it is important to identify whether this implicit behavioural knowledge of the actors also causes participants to anticipate their response, and identify the expected action even though it is not yet presented (i.e., during presentation of the neutral image). Due to the low number of anticipations (6.46% across both experiments), the data from both experiments were combined to increase power for a repeated measures ANOVA with the factors Expected Action (act with object, turn from object) and Response (typical action identified, atypical action identified), with Experiment (Experiment 1a, Experiment 1b) as a factor of no interest, for those participants who made at least one anticipation, *n* = 31. There was a trend towards significance for the main effect of Response, *F*[1,30] = 3.214, *p* = .083, $\eta\rho^2$ = .097, with more anticipations for typical actions (*M* = .011, *SE* = .003) than atypical actions (*M* = .008, *SE* = .003). However, there was no main effect of Expected Action (*F* = 2.059), nor an interaction between the two (*F* = .145), and the factor Experiment did not interact with the other two factors, all *F* ≤ 1.136. Thus, the anticipations show that others' behavioural tendencies not only affect the speed of action identification, but also sometimes caused participants to anticipate the forthcoming response while the neutral image was still onscreen.

Discussion

Experiments 1a and b provided first evidence that action observation draws upon knowledge of how others act in different situations. Participants identified actions more rapidly if they were typical for the given actor, compared to the same action when executed by an actor for which they were atypical. These effects were found even though actor and situation were task-irrelevant, and even though the overall frequency of actions was controlled across actors and situations. The effects therefore provide a first indication that participants are learning the behavioural tendencies of the actors with the different objects, and reactivating this knowledge in a person-specific manner, such that their most likely actions are predicted and are easier to identify in a given situation. This supports the theory that we store information about people in terms of the ‘intentional relations’ they have in given situations (Barresi & Moore, 1996).

In both experiments action typicality predominantly affected identification of actions towards objects (kicking, typing) rather than actions away from them. Although not directly predicted, this fits with research that action prediction specifically occurs for meaningful actions towards objects (for a review see Bach et al., 2014), whereas object avoidance is coded as an inhibition of approach (Friedman & Leslie, 2005; Leslie, German, & Polizzi, 2005). Indeed, even though there are neuronal populations for representing intransitive action (Fadiga et al., 1995; Press et al., 2012), the majority of mirror neurons, one of the proposed core mechanisms of action understanding and prediction, only fire for actions towards objects (for a review see Fabbri-Destro & Rizzolatti, 2008, see also Enticott, Kennedy, Bradshaw, Rinehart, & Fitzgerald, 2010). Furthermore, such object-directed actions in humans have been shown to be represented in dedicated neuronal populations (Agnew, Wise, & Leech, 2012), with further evidence that, in humans, afforded interactions with an object are perceived and predicted more readily than non-afforded actions (Bach et al., 2005; van Elk et al., 2009). Similarly, even high level predictions of what other people will do (e.g., in theory of mind tasks) occur for approach-related behaviours, but not for avoidance (Friedman & Leslie, 2005; Leslie et al., 2005). Thus, the current results are in line with the ‘special status’ assigned to object-directed action within action observation. Similarly, the current results support the theory that ‘intentional relations’ between people and situations are only formed for goal-directed behaviours (Barresi & Moore, 1996).

The present effects are unlikely to result from strategic responses by participants with explicit awareness of the experimental manipulations for several reasons. First, only five participants explicitly recognized the experimental manipulation when probed after the experiment (and these were removed from analysis). Second, effects reflecting strategic response preparation should have been found irrelevant of action type (act towards, turn away) rather than primarily for actions towards objects, especially as overall response times between these conditions did not differ. Finally, strategic response preparation effects should be seen not only in response time, but specifically in error rates (Dale, Duran, & Morehead, 2012; Duran & Dale, 2009; Marcus, Karatekin, & Markiewicz, 2006), yet no such effects were found. Of course, the anticipation data – the responses that participants made during the neutral image before the action was seen – could be considered a form of error data because participants responded before the action had been seen. Whilst power was low due to the reduced sample size (which limits the potential conclusions that can be drawn), the data replicated the prediction effect seen in the response times as there were more anticipations responding that the action would be ‘typical’ than ‘atypical’.

Importantly, despite an inability to identify the experimental manipulation, participants could make reliable judgments about which objects the two actors liked more, and which they tended to interact with more. Thus, if John was typically seen interacting with the computer but turning away from the football, he was later judged to like computers more than footballs. This implies that such person-knowledge is not fully opaque, but can be accessed – in an offline, retroactive fashion – to generate behavioural information, perhaps by playing through, in one's mind, relevant instances in memory. Interestingly, this ability to access such knowledge was not strongly related to the prediction effects in response times as even those participants that did not show any effects on the liking ratings still showed significant prediction effects in response times. Therefore, prediction effects in explicit ratings and action identification are at least partially dissociable, further highlighting that the facilitated action identification responses were not due to strategic anticipatory processes of participants that "saw through" the experimental manipulation.

This data is therefore consistent with the notion of person-specific models, which learn the behavioural tendencies of how individuals act in certain situations, and reactivate this knowledge when the specific individual is seen again in a similar situation. However, the data cannot fully reject other potential alternative hypotheses such as stimulus response learning for example, that participants simply learn which motor responses (button presses) are most likely required when seeing a person in a given situation. Such accounts would also hypothesise facilitated responses to the more frequent stimuli. However, stimulus response learning would not hypothesise the interaction between action type and expectancy, instead it would hypothesise that independent of action type (act towards or turn away from the objects), response times should be faster when participants see the most frequent pairings (e.g., John kicking the ball, John turning from the computer). Thus, there is tentative evidence against these alternative accounts, but the current findings must be replicated, and further evidence is required, to more conclusively support the person-model hypothesis.

Experiment 1c – making the behavioural tendencies explicit

The previous experiments suggested an implicit effect to the facilitated response times seen for typical compared to atypical actions for specific actors in specific situations. Experiment 1c investigated the influence of explicitly providing participants with the behavioural tendencies of the two actors. Whereas previously participants ‘chose’ which information to pay attention to, here the behavioural tendencies of both actions towards and away from the objects were highlighted. Thus, it was hypothesised that there would be facilitated response times for both action types when they were typical rather than atypical for the actor, and that such explicit effects would affect error rates as well (Dale et al., 2012; Duran & Dale, 2009; Marcus et al., 2006).

Method

Participants

40 participants (28 females, mean age = 29.98 years, SD= 14.44; 33 right handed) took part in the study in exchange for £4 or course credit.

Materials, procedure and apparatus

The computer task was identical to Experiment 1b but, before it began, participants were told that one actor would mostly kick the football and turn away from the computer, and that the other actor would do the opposite. Furthermore, there were no post-experiment questionnaires.

Results

Response times

12.18% of trials were excluded in total (5.72% for error trials, 2.67% for scores greater than 3 SD from the mean, and 3.79% for responses that were either too slow, involved a double response from the participant, were an anticipatory response, or where Presentation timing was uncertain). The remaining data were analysed with a repeated measures ANOVA with the factors Observed Action (act with object, turn away from object) and Action Typicality (typical, oddball).

This analysis revealed a main effect of Observed Action, $F[1,34] = 4.915$, $p = .033$, $\eta\rho^2 = .126$, with faster response times for actions towards ($M = 471.09$, $SE = 13.60$) than away ($M = 486.45$, $SE = 11.90$) from objects. There was also the predicted main effect of Action Typicality, $F[1,34] = 29.979$, $p < .001$, $\eta\rho^2 = .469$, with faster responses to typical ($M = 469.37$, $SE = 11.92$) relative to atypical ($M = 488.21$, $SE = 12.90$) actions. However, there was no interaction between the two factors, $F[1,34]= 2.306$, $p = .138$, $\eta\rho^2 = .064$. Follow-up t-tests revealed that the RT advantage for typical relative to atypical actions was not only present when the actors acted with the objects (kicking a football, typing at a computer), $t[34]= 5.356$, $p < .001$, $d = .28$, but also when they turned away from them, $t[34]= 3.467$, $p = .001$, $d = .21$.

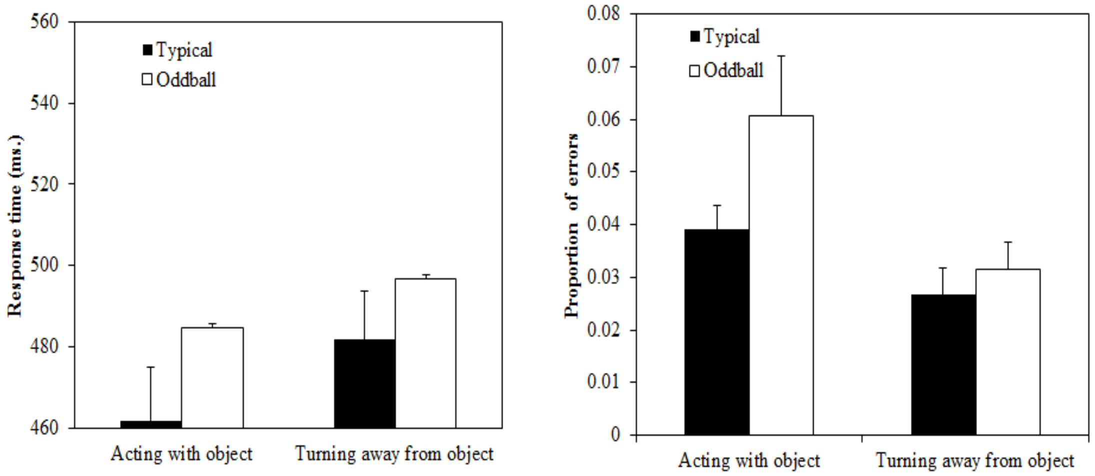

Figure 2.3 Response time and proportion of error data for Experiment 1c.
The left panel shows average response times, and the right panel shows the average proportion of errors. The black bars reflect actions typical of this individual in this situation, and the white bars show the action typical of the other individual. The error bars show the standard error of the mean.

Errors

The same ANOVA on the error data revealed a main effect of Observed Action, *F*[1, 33] = 6.051, *p* = .019, $\eta\rho^2$ = .155, with more errors in the acting towards (*M* = .05, *SE* = .01) than turning away (*M* = .029, *SE* = .004) trials. There was also a main effect of Action Typicality, *F*[1, 33] = 4.857, *p* = .035, $\eta\rho^2$ = .128, with more errors for atypical (*M* = .05, *SE* = .01) than typical (*M* = .03, *SE* = .01) trials. However, there was no interaction between Observed Action and Action Typicality, *F*[1,33] = 1.774, *p* = .192, $\eta\rho^2$ = .051. Follow-up t-tests revealed more errors for atypical relative to typical actions when the actors acted with the objects (kicking a football, typing at a computer), *t*[33]= 2.026, *p* = .051, *d* = .37, but not when they turned away from them, *t*[33]= .794, *p* = .433, *d* = .00.

Discussion

Experiment 1c replicated the effect of faster response times for typical than atypical actions, when typicality was explicitly provided to participants. Again, supporting the hypothesis that we store information about people in terms of the 'intentional relations' they have in given situations (Barresi & Moore, 1996). However, in this case the facilitated response occurred irrespective of action type (acting towards or turning away). In contrast, during the previous (implicit) tasks, a predictive bias was seen more strongly for acting towards trials. This difference likely results from the fact that, here, the behavioural tendencies of each actor were explicitly stated for both action types, in other words, that one actor would interact with one object, but turn away from the other. This highlights a dissociation between explicit and implicit awareness - when no explicit information is given, the focus is on goal-directed actions towards objects, but when explicit information is given, predictions are made more equally to both actions towards and away from objects.

Other aspects of the data support this dissociation. For example, a comparison of the effect size for the main effect of Action Typicality for Experiment 1c (.469), and Experiment 1a (.058) and Experiment 1b (.057) shows a larger effect when participants are explicitly told the pattern than during the more implicit tasks. Moreover, this is the first study in this series to show a significant difference in error rates for typical and atypical actions. This error data is therefore in line with the idea that explicit awareness allows participants to prepare a response ahead of time, which then leads to erroneous responses if the actor does not behave according to predictions. Indeed, in other non-social predictive coding paradigms just such an error effect is typically reported when participants make explicit behavioural wagers for what will happen in a given situation (Dale et al., 2012; Duran & Dale, 2009; Marcus, Karatekin, & Markiewicz, 2006).

Whilst the potential for at least partially separable implicit and explicit awareness of the person-models was not a main aim of the thesis, it does fit in with prior research. COVIS models (COmpetition between Verbal and Implicit Systems; e.g., Ashby et al., 1998; Maddox & Ashby, 2004) suggest that there are two learning systems; verbal categorisation (for when the rules of learning can be easily verbalised), and implicit categorisation (when the rules are more complex such that they cannot be verbalised). Thus, it could be argued that the previous experiments (1a and 1b) used the implicit categorisation data as the person-models were not easily verbalisable to participants. However, in the current experiment, the person-models were verbalised to participants and so they were able to use the explicit verbal categorisation learning system. This link is, of course, tentative for the time being as COVIS models are typically based on very basic, non-social stimuli and this is, to my knowledge, the first time these models have been applied to more higher level, social situations.

Thus, the current evidence suggests that there is a greater focus on object-directed actions unless attention is explicitly drawn to the turning away trials too (as in the current experiment). However, this act of bringing person-models into explicit awareness, as in Experiment 1c, is a much more artificial task – often in social interactions we are not told which information to focus on, but must make that decision (implicitly or explicitly) ourselves. Also, the current experiment cannot yet differentiate the person-model hypothesis from simple stimulus response learning accounts. Therefore, the next experiment tests the influence of explicit knowledge in a more ecological way. Rather than simply giving the behavioural tendencies of the actors, Experiment 1d gives a hypothesis for how actors tend to behave in much the same way as gossip occurs.

Experiment 1d – the effects of an explicit hypothesis for the person-model when trials match or mismatch the hypothesis

Experiment 1d rests on the idea that learning by observation is not our only information source. People love to gossip (Beersma & Van Kleef, 2012), so mutual acquaintances can provide further information about other individuals, for example, using gossip. With gossip, people communicate their (first-hand or second-hand) experiences with the individual and the 'gossipee' is then left to assess this when they interact with this individual themselves. For example, John might say to Claire that George is usually very cheerful. When Claire meets George for the first time she will likely compare his demeanour with John's 'cheerful' hypothesis. George may be cheerful during their encounter or he may not. Thus, Experiment 1d provides a first test of what happens when observers are given both accurate and inaccurate information about the behavioural tendencies of two actors.

The current study attempted to capture this explicit social knowledge, and test whether similar internal models are established when given such explicit knowledge about individuals, and how such explicit knowledge interacts with (potentially conflicting) information provided by the real-world action likelihoods of the individuals. Indeed, social psychology has already shown the influence of explicit person descriptions on subsequent person-memory and reading times (C. E. Cohen, 1981; Heider et al., 2007; Srull & Wyer, 1989; Stangor & McMillan, 1992; Stern et al., 1984). Experiment 1d goes further to test the person-specific nature of these internal models.

At the start of the experiment, participants were given information on how the actors typically behaved ("John typically kicks the ball, but rarely types on the computer"). They performed the same action identification task as in the previous experiments, but were asked to assess, after observing these actors across a block of trials, their level of agreement with the person-description. Across blocks, the actual behavioural tendencies could either follow the explicitly provided information (in 75% of the cases), contradict the explicit information (the actors perform the opposite action in 75% of the cases), or the actors could show no preference for any action (all actions were displayed an equal number of times).

This task pits implicitly derived internal models of other people from those derived by explicit information. It tests, first, whether explicit information about others leads to similar biases in identifying their actions as the implicit information, and leads to a "social confirmation bias" where people judge actions based on what they expect to happen rather than what is perceived. Second, it tests the extent to which explicit and implicit predictions interact.

It is hypothesized that independent of explicit information, statistical regularities within the observed stimuli will still influence response times such that responses are facilitated for more frequent actions. In contrast, the explicit information should exert a stronger influence on the error data. As suggested in Experiment 1c, and prior research in non-social predictive coding (Dale et al., 2012; Duran & Dale, 2009; Marcus et al., 2006) participants may use the explicit information to begin preparing their responses.

Method

Participants

49 participants (39 females, mean age = 20.92 years, SD = 6.06; 44 right handed) took part in the study in exchange for course credit. One participant was excluded for making more than 10% errors.

Materials and Apparatus

Stimuli and the course of each trial were identical to the previous experiments. The experiment was controlled with E-Prime 2.0 (Psychology Software Tools, Pittsburg, PA), and responses were recorded with button boxes.

The only questionnaire used was the social intelligence scale (Silvera, Martinussen, & Dahl, 2001). The scale consists of 21 questions each on a 7-point Likert scale. Examples of questions are “I can predict other peoples’ behaviour”, “I often feel uncertain around new people who I don’t know” and “I can often understand what others mean through their expression, body language, etc.”. However, there were no significant correlations between this scale and the effects seen so this will not be discussed further.

Design and Procedure

Participants received detailed instructions and then underwent 16 practice trials of the action identification task with a third actor who did not appear in the main experiment. Participants were then informed of the secondary task of assessing the hypotheses, and were given a practice hypothesis that the actor typically kicked the ball, but turned away from the computer. This was followed by 12 practice trials in which 8 of the trials supported the hypothesis and 4 contradicted it. Participants then rated their agreement with the hypothesis on a 4-point scale (1 = “completely disagree”, 4 = “completely agree”). Practice trials consisted of a neutral photograph for 500 ms and then the action photograph for a maximum of 2000 ms. Feedback was given for slow or erroneous responses.

Once the task was understood, participants were given an explicit description about the actors’ typical behaviour (e.g., John typically kicks the ball, but turns away from the computer, and Claire typically types on the computer, but turns away from the ball), and told that they had to evaluate the appropriateness of this behaviour description after seeing the actors' actual behaviour in each of the experiments' nine blocks (32 trials each). At the start of each block participants were reminded of the explicit person description (which remained the same throughout the experiment), told that this was a new set of trials and to ignore what they had previously seen. They then performed the action identification task of Experiment 1b. Unbeknownst to participants, blocks conformed to the prior person description (75:25), contradicted it (25:75), or showed no preferred behavioural tendencies (all actions were equivocal; 50:50). After each block, participants rated the extent to which they agreed that the actors' behaviour corresponded to the person descriptions at the start of the experiment.

After the computer task, the social intelligence scale was administered.

Results

Response times

7.26% of trials were excluded in total (5.33% errors and 1.93% for RTs greater than 3 SD from the mean). The remaining data were analysed with a repeated measures ANOVA with the factors Action-Description Match (the observed action follows/does not follow the person description), Block-Description Match (observed statistics in the current block matches the person description, are equivocal, contradicts the description), and Observed Action (act toward object, turn from object).

The analysis of RTs (Figure 2.4, left panels) revealed no main effect of Block-Description Match, $F[2,44] < 1$, nor Action-Description Match , $F[1,47] < 1$, nor Observed Action, $F[1,47] < 1$, providing no evidence that actions that matched the explicit information were generally identified more quickly than mismatching actions. However, there was an interaction between Block-Description Match and Action-Description Match, $F[2,46] = 5.062$, $p = .010$, $\eta\rho^2 = .180$. Whilst actions that matched the hypothesis sped up response times when this was supported by statistical regularities ($t = 2.260$, $p = .029$, $d = .66$), this effect was eliminated when the action likelihoods were equal ($t < 1$), and reversed when the action that matched the hypothesis was actually the infrequent alternative ($t = 2.060$, $p = .045$, $d = .60$). This is direct evidence that action identification times are not affected by explicit information about the actors, but – replicating Experiment 1a and 1b – follows the prior action frequencies, speeding up the identification of frequent actions, and slowing down the identification of infrequent actions. There were no other effects (Fs ≤ 2.391).

In previous "implicit" experiments, action likelihood specifically affected actions with objects, but not withdrawals from them. Therefore, planned comparisons were conducted with the Block-Description Match and Action-Description Match factors separately for actions towards objects and withdrawals. As expected from previous experiments, for the withdrawal trials there were no significant effects (all Fs ≤ 1.376), although, numerically, they showed the same pattern as actions towards objects. The acting towards trials, however, revealed the relevant interaction between Block-Description Match and Action-Description Match, $F[2,46] = 4.471$, $p = .017$, $\eta\rho^2 = .163$. This confirms that, as previously found, the effects of statistical regularities on response times were primarily driven by actions towards objects, but not withdrawals.

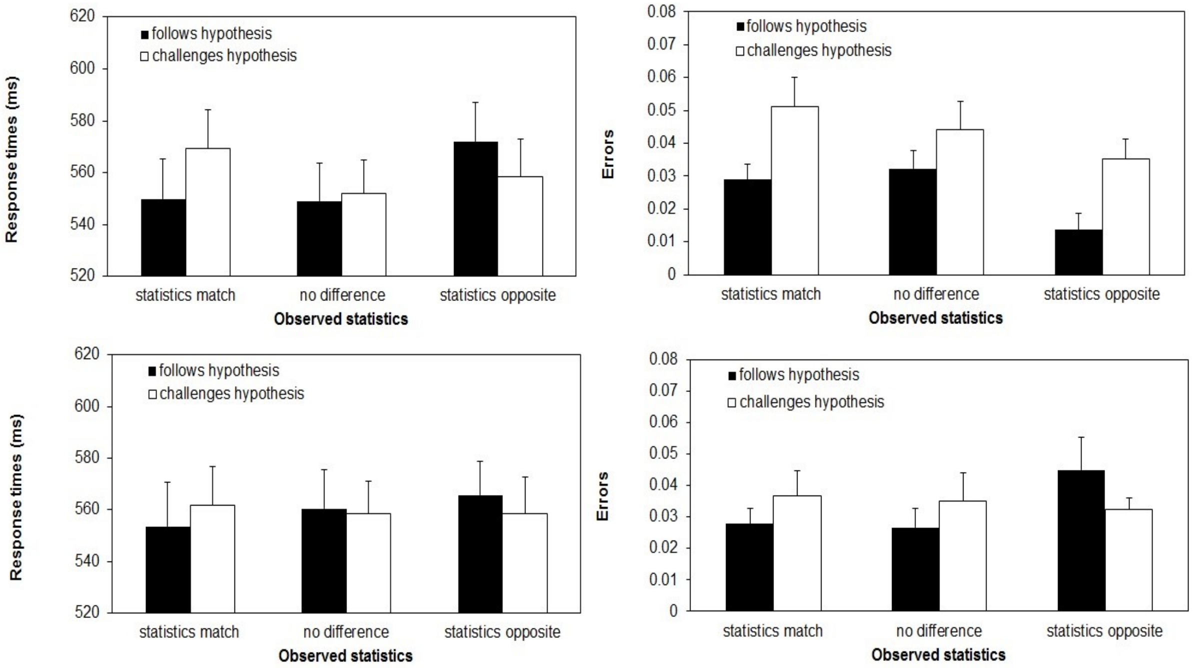

Figure 2.4. Response time and proportion of error data for Experiment 1d

The left panel shows the response times and the right panel shows the proportion of error rates. The black bars represent trials which followed the hypothesis and the white bars represent trials which are the opposite of the hypothesis. The top panels indicate actions towards objects and the bottom panels indicate turn away actions.

Error rates

Error rates were analysed with the same ANOVA model, and revealed no main effect of Block-Description Match, $F[2,46] = 1.099$, $p = .342$, $\eta\rho^2 = .046$, nor of Observed Action, $F[1,47] = .360$, $p = .552$, $\eta\rho^2 = .008$, but a main effect of Action-Description Match , $F[1,47] = 7.404$, $p = .009$, $\eta\rho^2 = .136$. Participants made more errors, and identified the wrong action, when actions conflicted with the explicit expectation. This was qualified by an interaction of Action-Description Match and Observed Action, $F[1,47] = 6.385$, $p = .015$, $\eta\rho^2 = .120$, showing that the increase of errors for non-expected actions was stronger for actions towards objects than withdrawals. There was also an interaction of Block-Description Match and Observed Action, $F[1,47] = 3.790$, $p = .030$, $\eta\rho^2 = .012$.

Planned comparisons for acting towards objects revealed a main effect of Action-Description Match, *F*[1,47] = 15.740, $p < .001$, $\eta\rho^2 = .251$, and a main effect of Block-Description Match, *F*[1,47] = 6.348, p = .004, $\eta\rho^2 = .216$, but no interaction between the two, $F = 1.178$. Pairwise comparisons revealed a higher proportion of errors for frequent (*M* = .035, *SE* = .005) compared to infrequent (*M* = .021, *SE* = .003) actions, and a higher proportion of errors for mismatching (*M* = .038, *SE* = .004) compared to matching (*M* =. 021, *SE* = .002) trials, $p < .001$.

However, there were no significant main effects or interactions for withdrawals ($F \leq 1.265$). As such, participants tended to judge actions towards objects (but not withdrawals) in light of the prior hypotheses irrespective of the actual statistical regularities.

Behaviour ratings

Data from the ratings indicating to what extent the individuals followed the predicted behaviour was analysed with a one-way ANOVA with the factor Block-Description Match (Blocks either matched the hypothesis, mismatched the hypothesis, or showed each action equally). This analysis revealed a main effect of Block-Description Match, *F*[1, 143] = 72.053, $p < .001$, showing that participants were well able to extract the actual behavioural statistics of the individuals in each block. Participants tended to agree more with the hypothesis when what they saw matched what was hypothesised compared to when they saw equivocal trials (where actions were performed equally often for each actor with each object) or trials which opposed the hypothesis. Further post hoc t tests showed that participants were more likely to agree with the hypothesis when what they saw matched the hypothesis than when they saw either equal actions for both actors on both objects, *t*[47]= 8.201, $p < .001$, or when what they saw was completely the opposite to what was hypothesised, *t*[47]= 10.391, *p* < .001. Moreover, participants were more likely to agree with the hypothesis when they saw equal actions for both actors on both objects compared with actions that completely went against the hypothesis, *t*[47]= 6.096, *p* < .001.

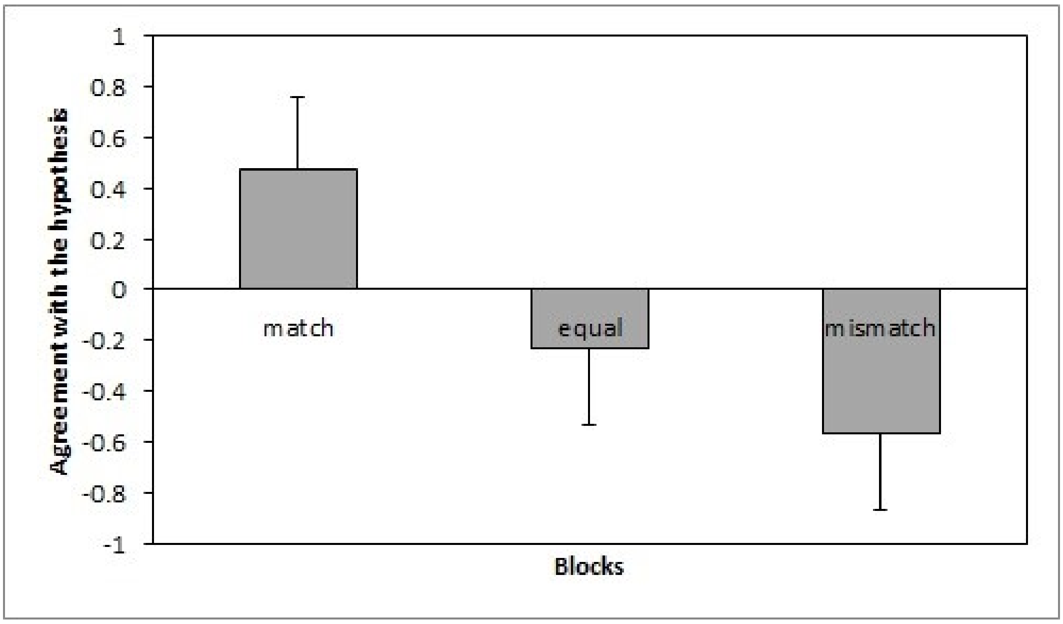

Figure 2.5. Experiment 1d behavioural ratings
The graph depicts average agreement with the behavioural ratings across blocks that either matched or mismatched the hypothesis, or showed each actor interacting with each object equally. The error bars show the standard error of the mean.

Discussion

Experiment 1d provided further evidence for person-specific internal models which predict how interaction partners behave in different situations. It demonstrated that such internal models can originate from two different sources, implicit information about others' action likelihoods and explicit knowledge about how others will behave, each reflecting different mechanisms. Again, it provided support for COVIS hypotheses of two different learning systems (explicit verbal categorisation and implicit non-verbalisable categorisation; Ashby et al, 1998; Maddox & Ashby, 2004) within more social stimuli.

As in the previous experiments, implicit information about others' action tendencies provided by their prior behaviour affected action identification times, specifically for actions towards objects, but not withdrawals. Actions were identified more quickly when they were more frequently carried out by an actor in the given situation, compared to actions that this actor carried out less frequently. In contrast, explicit information about others' behaviour did not affect action identification times; instead it affected error rates. Participants made more errors, and identified an action incorrectly, whenever it was not the action explicitly expected for this actor. This reveals that while action identification times follow the statistical regularities, the error data follow participants' explicit knowledge. Participants sometimes classified an action as an action towards an object even though it was a withdrawal, simply because this reflected the explicit information they had received. For example, if the explicit hypothesis was that John will mostly kick the ball and turn away from the computer, they would be more likely to make an error response when he turned away from the ball or typed at the computer.

This unique effect of explicit information on error rates is consistent with Experiment 1c where, similarly, explicit information affected error rates. In addition, it matches other research on predictive coding in the non-social domain. Implicit information about statistical regularities often affects response speed, perhaps due to perceptual (or motoric) anticipations of forthcoming events (Dale et al., 2012). Explicit information, in contrast, might induce a tendency of participants to make behavioural "wagers" about what will be observed, which allows them to overtly test their hypotheses about the regularities guiding the events' (or other people's) behaviour (Marcus et al., 2006; see also Duran & Dale, 2009.). Indeed, in a recent study, it was exactly these explicit behavioural wagers that were associated with the explicit (rather than implicit) recognition of the underlying rules that governed the event sequences (Dale et al., 2012). Thus, even though it must be confirmed in future studies, the present dissociations are in line with predictive coding work that sees explicit behavioural wagers as key learning mechanisms for explicit learning and verification of hypotheses.

This experiment has shown, first, that statistical regularities of how someone typically acts in a given situation informs ones' knowledge about them, which is then reactivated when that person is re-encountered in that situation. Second, however, they have provided evidence for a parallel stream of predictions emerging from high-level explicit information that directly affects decision making of participants. This, again, provides support for the hypothesis of 'intentional relations', and how these can be formed for both concrete and abstract behaviours (Barresi & Moore, 1996). They also provide evidence against a simple stimulus learning account. Such an account would hypothesise that, as in Experiment 1c, response times should be faster when participants see the most frequently paired stimuli (e.g., John kicking, John turning from the computer) irrelevant of any higher-level information (such as the explicit hypothesis given to participants).

However, the experiments so far only provide an indirect measure of prediction (by assessing response times and error rates), therefore, Experiment 1e investigates the influence of person-models on actual predictions by partially replicating the paradigm, but with intermittent 'online' prediction trials where participants must say what the actor will do next with a specific object.

Experiment 1e: online social action prediction

For Experiment 1e the paradigm was adapted to include ‘prediction’ trials whereby the participants see the neutral photographs of the actors next to the object and must report what they believe happens next: whether the actor will interact or turn away from the object. If internal models are being used to make action predictions, and if participants can access this knowledge during the experiment, there should be more responses in line with typical than atypical actions within these trials.

First, results in the ‘normal’ trials should reflect the previously seen response time facilitation towards typical than atypical actions. Second, there should, again, be evidence that participants can relay information from the person-models post hoc when asked specifically and directly about this information. Finally, in the ‘prediction’ trials there should be evidence of using the information from the person-models to make the predictions. If, as hypothesised, the previous findings reflect prediction effects based on these person-models, performance on these ‘prediction’ trials (i.e., responding in line with the person-models) should be better than chance. However, if these models are as implicit as Experiment 1a and b suggest then these responses should not be made in 100% of the ‘prediction’ trials. Thus, if John typically kicks the ball, participants should be more likely to say that he will kick the ball during the prediction trials at a rate that is more often than chance, but less often than if they had complete awareness of the experimental manipulation (i.e., in 80% of trials). However, if the previous results are due to a simple stimulus-response mapping, then the prediction trials should show explicit awareness because participants will just press the button they have learned to press with that stimuli.

Method

Participants

46 participants (38 females, mean age = 19.59 years, *SD* = 2.80; 39 right handed) took part in the study in exchange for course credit. Three participants were excluded for making more than 10% errors, and a further three were excluded for identifying the critical manipulation within the funnel debrief.

Materials, apparatus and procedure

The social intelligence scale (Silvera et al., 2001) was administered, but did not correlate with the principal task so will not be discussed further.

The main computer task was identical to Experiment 1b except that interspersed within the normal trials (288 in total) were 48 ‘prediction’ trials where only the neutral photograph was shown, and participants had to indicate whether the actor would interact or turn away from the object. Whilst participants saw one fluid block of trials, the trial order was pseudo-randomised to more equally spread the prediction trials throughout the experiment. As such, the first 16 trials depicted the typical actions (e.g., John kicking the ball and turning away from the computer) followed by blocks with a ratio of 40 ‘normal’ trials (with the same typical: atypical ratio of Experiment 1b) to 8 prediction trials. The exit questionnaires were identical to previous experiments.

Results

Funnel debrief

The average overall ease of the task was perceived to be 6.28 (out of 10). The actors and the actions/objects were equally salient with neither being easier to identify conclusively (see Table 2.4).

Table 2.4

Data showing which actor and which object/action participants rated as easier to identify for Experiment 1e

Character	**Easiest to identify**	**Object/Action**	**Easiest to identify**
Claire	15	**Ball/kick**	14
John	8	**Computer/type**	13
Neither Claire nor John	23	**Interacting with an object**	6
		Turning away from an object	3
		None	9

For Experiment 1e, thirty-six participants (78.26%) did not identify anything unusual about the stimuli, thirty-two (69.57%) did not identify any patterns in the stimuli, and the remaining gave similar proposed patterns as in previous experiments. As aforementioned, one participant correctly gave the manipulated pattern, and two said they had spotted a pattern, but did not specify what it was; all were removed from further analysis (6.52%).

7.80% of trials were excluded in total (3.28% for error trials, 0.88% for scores greater than 3 SD from the mean, and 3.64% for Presentation uncertainties). For the response time data, erroneous responses were also excluded. The remaining data were analysed with a repeated measures ANOVA with the factors Observed Action (act towards, turn away) and Action Typicality (typical, oddball), separately for response times (RTs) and Error rates.

Response times

The analysis revealed a main effect of Action Typicality, *F*[1,39] = 14.797, *p* < .001, *ηρ²* = .275, with faster RTs for typical (*M* = 519.73, *SE* = 11.00) than atypical (*M* = 538.08, *SE* = 12.02) trials. However, there was no main effect of Observed Action, *F*[1,39] = 2.412, *p* = .128, *ηρ²* = .058, and no interaction between these factors, *F*[1,39] = 1.646, *p* = .207, *ηρ²* = .040. As can be seen in Figure 2.6, actions towards objects (kicking a football, typing on the computer) were identified more quickly when they were typical than atypical for the actor*,* *t*[39] = 3.741, *p* = .001, *d* = .32, and, numerically, the same pattern was present for the turn away trials, *t*[39] = 1.568, *p* = .125, *d* = .15.

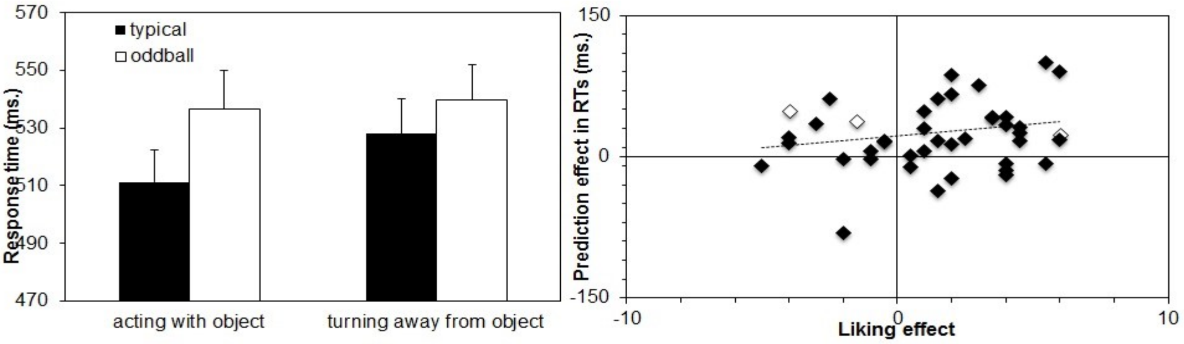

Figure 2.6 Response time and exit questionnaire data for Experiment 1e
Left panel: average response times, the left bars show identification of actions towards objects (typing on a computer, kicking the football) and the right bar shows actions away from objects. The black bars reflect actions typical of this individual in the given situation, and the white bars show the action typical of the other individual. Error bars show the standard error of the mean.
Right panel: correlation between prediction effects in the RTs for actions towards objects and the corresponding differences in perceived object liking, for individuals who either identified (*unfilled diamonds*) or did not identify (*filled diamonds*) the behavioural pattern.

Error rates

The analysis revealed no main effect of Observed Action, *F*[1,38] = .236, *p* = .630, $\eta\rho^2$ = .006, nor of Action Typicality, *F*[1,38] = 3.122, *p* = .085, $\eta\rho^2$ = .076, and no interaction between the two factors, *F*[1,38] = .736, *p* = .396, $\eta\rho^2$ =.019. As can be seen in Table 2.5, actions towards objects (kicking the football, typing on the computer) led to a (numerically) higher proportion of errors when they were typical for the actor compared to when they were atypical, *t*[38] = .781, *p* = .439, *d* = 0. The same pattern was seen for turn away trials, but here the difference was statistically significant, *t*[38] = 2.059, *p* = .046, *d* = .28.

Table 2.5

Means and SDs for the proportion of errors for Experiment 1e

	Typical trials – Mean (SD)	**Oddball trials – Mean (SD)**
Acting towards objects	.04 (.03)	.04 (.04)
Turning away from objects	.04 (.04)	.03 (.04)

Prediction trials – number of anticipations

For the prediction trials, the responses were converted into an ‘expectancy’ percentage (hereafter expectancy score). First, the same exclusion criteria as previous analyses (z scores, etc.) were applied to the prediction trials. Second, all prediction trial responses were separated into whether they had responded in line with prior behaviour (i.e., were expected) or whether they went against prior behaviour (i.e., were unexpected). Third, the expectancy scores were divided by the total number of responses. These scores were then compared to chance (50%) and to explicit expectancy (80%) using one sample t tests.

Participants performed significantly better than chance (*M*=.54, *SD*=.11), *t*[36] = 2.597, *p* = .013, but significantly worse than explicit expectation, *t*[36]= 15.012, *p* < .001. Thus, participants were predicting that the actors would behave as they had done in prior trials (i.e., if they mostly saw John kicking the ball then they were more likely to say that he would kick the ball than turn away from it in these trials), but this information did not reach explicit levels of expectation.

There was a positive correlation between the anticipation expectancy data and the anticipation response time effect (i.e., when the typical trials were subtracted from the atypical trials; *r* = .532, *n* = 40, *p* < .001). Those participants who took more time to respond were more likely to respond in line with the (typical) prior behaviour of the actor.

Liking

As before, objects that were typically acted upon by an actor were rated as more liked (*M* = 1.98, *SD* = 1.38) than objects they typically turned away from (*M* = .44, *SD* = 1.94), *t*[36] = 3.344, *p* = .002, *d* = .91. A regression analysis measured the relationship between apparent explicit awareness as seen in the liking ratings, and the response time effect for actions towards objects. Here, explicit awareness did not predict RTs (*r* = .190, *n* = 43, *p* = .223), however, as in previous experiments, the intercept was significantly different from zero (*t* = 2.719*,* *p* = .010). This indicates that even those participants with no apparent explicit awareness in the liking ratings still showed significant RT prediction effects. The same analysis was performed for the prediction trial RT data. Here, explicit awareness did not predict RTs ($r = -.006$, $n = 40$, $p = .971$) and the intercept was not significantly different from zero ($t = .944$, $p = .513$). However, the same analysis was carried out with the expectancy scores from the prediction trials, and here explicit awareness did predict expectancy ($r = .327$, $n = 40$, $p = .039$) and the intercept was significantly different from zero ($t = 28.411$, $p < .001$). This shows, first, that those with more explicit awareness gave responses in line with typical behaviours for each actor during the online prediction trials. Second, those participants who rated the typically acted upon objects as more liked had a higher expectancy score (i.e., responded more in line with the person models during the online prediction task).

Discussion

Whilst the previous experiments in this chapter demonstrated that action observation draws upon internal models of how others typically act in different situations, Experiment 1e investigated whether participants could access their internal models to perform an explicit 'online' version of the task to make predictions about how the two individuals would behave. Thus, at various intervals the actor was shown neutrally with the object and participants reported what they expected them to do next. As before, typical actions were responded to faster than atypical actions. However, whilst the pattern was numerically the same, the interaction between Observed Action and Action Typicality did not reach significance.

In the discussion of Experiment 1d it was proposed that internal models are created relatively implicitly, but that they can be tested in the form of explicit wagers (Marcus et al., 2006; see also, Duran & Dale, 2009) against incoming information. As the explicit prediction task in this experiment was online, such processing was ongoing throughout the task. Thus, the act of having to make explicit predictions at forced intervals rather than in the natural way that explicit wagers occur (when sufficient evidence is deemed to have been acquired) may have disrupted the implicit learning mechanism by the increased attention interfering with implicit learning. This may also be responsible for the trend towards a higher proportion of errors for typical than atypical trials suggestive of a speed-accuracy trade-off. Indeed, previous explicit studies also elicited effects in the errors (see Experiments 1c and d). However, the speed-accuracy trade-off here may simply reflect an increased confidence in participant responses, or an influence of their explicit predictions during the ‘prediction’ trials affecting the ‘normal’ trials.

For the explicit prediction trials, participants were better than chance at identifying which actions come next (based on prior actor behaviour), but were much worse than explicit expectation. This provides further evidence that participants are forming person-specific internal models, which are activated when the actor is re-encountered in that situation, and against the argument that the response time advantage for typical trials reflects a mere strategic response bias. If the results really were just a strategic response bias (or even the result of stimulus response learning) then, during these trials, responses should have been close to (or even beyond) expectancy levels as participants should just have seen John with the ball and been primed to press the UP arrow key. However, this was not the case.

Strikingly, even though now there was an explicit prediction task, participants were still unable to identify the experimental manipulation during a funnel debrief, but they could make reliable judgments about which objects the two actors liked more based on which objects they more frequently interacted with. This, again, highlights at least a partial dissociation between implicit and explicit knowledge. Interestingly, those people with more explicit awareness (indicated by a higher expectancy score) took longer to respond, and were more likely to respond in line with the prior behavioural tendencies during the liking questions. This suggests evidence of the prediction effects being based on social learning rather than on a mere stimulus response bias.

General discussion

The experiments in this chapter provided a first test of whether observers are sensitive to the likelihood that an actor carries out a given action in a given situation, and then re-activate this knowledge whenever they are seen again. Indeed, the experiments showed that actions were identified faster if they were, in previous encounters, typical of the particular individual in that situation, compared to actions that were typical of another actor. Thus, kicking a football, for example, was identified more quickly if carried out by an actor who typically kicks the football compared to another actor who typically turns from it. These effects of actor identity on action identification were found even though the overall likelihood of the actions was controlled across actors, and both actor and situation were completely task-irrelevant. These findings therefore show that people identify actions not only based on the available kinematic information, but that they routinely take into account who is acting and how they behave in different situations.

The effect of actor identity on action identification is in line with the notion that watching others can give rise to person-specific internal models of how they behave in different situations, and that this knowledge is re-activated whenever these individuals are seen again. The existence of such internal models of others' typical behaviour has been theoretically predicted (Barresi & Moore, 1996; Newen, 2015), and the current data now suggest that they influence action observation and bias it towards the typical actions so that they can be identified more readily (compared to less typical actions). Whilst previous research has shown that person-models provide a reference frame against which others' behaviour can be judged (Hastie, 1984; Srull et al., 1985; Stinson & Ickes, 1992), these studies have typically used explicit information and measures that were far removed from online action observation, such as reading times or memory about individuals (C. E. Cohen, 1981; Heider et al., 2007; Srull & Wyer, 1989; Stangor & McMillan, 1992; Stern et al., 1984). Other studies have shown that people re-activate general action-related information about others whenever they are seen (e.g., the body parts used in the sport of famous athletes, Bach & Tipper, 2006; Tipper & Bach, 2011; prior emotional expression or the direction of gaze, Frischen & Tipper, 2006; Halberstadt et al., 2009; Joyce et al., 2015). The current data expands these findings by demonstrating how knowledge of the behavioural tendencies of actors in specific situations facilitates the identification of forthcoming action in a predictive manner. As such, they provide initial evidence for a sophisticated mechanism for action predictions based on both, who does the action, and what they are acting upon, in line with the idea that humans represent others, at least in part, in terms of their likely behaviour towards objects in their environment (Barresi & Moore, 1996).

These findings also support recent predictive coding theories that social perception is not simply a bottom-up mechanism matching incoming kinematic information to own action knowledge (Iacoboni, 2009b; Rizzolatti & Craighero, 2004; Rizzolatti & Sinigaglia, 2010), but that action observation is guided by prior knowledge (Bach, Nicholson, et al., 2014; Csibra, 2008; Kilner et al., 2007). In such models, top-down information about the person (e.g., action tendencies, goals, beliefs) and their behaviour in different situations (e.g., objects available for goal achievement) are used to predict the most likely actions, which facilitates processing of expected actions and/or disrupts it when predictions mismatch reality (e.g., Bach, Nicholson, et al., 2014; Csibra, 2008;

Kilner et al., 2007). The current experiments expand prior research demonstrating that such expectancies are derived from social cues such as object information, emotional expressions or gaze (e.g., R. B. Adams et al., 2006; Bach et al., 2005; Bach, Peelen, & Tipper, 2010; Pierno et al., 2006), to include prior knowledge held about the individual and their behavioural tendencies. It suggests, therefore, that action observation combines evidence from multiple sources. This is similar to the argument made for more general models of predictive processing in social and non-social perception alike, which are assumed to combine different sources of top-down information with bottom-up input to identify the most likely incoming stimulus (Kanai et al., 2015; Zaki, 2013).

The implicit-explicit dissociation

A key finding of the current experiments is the highly implicit and automatic nature of the person-models. Speeded up response times for predicted actions are present even in those participants that were unaware of the manipulated behavioural tendencies (Experiments 1a and b). Moreover, participants could relay information from these person-models when given direct and specific questions about the underlying manipulation after the experiment, such that they accurately reported which actor "liked" an object more, or interacted with it more. Importantly, however, regression analyses showed that even those who could not provide any explicit information about the manipulation still showed the prediction effect in the response times. This suggests a dissociation between the use of implicit and explicit knowledge in the present tasks and, particularly, that explicit knowledge is not necessary for the internal models to guide action observation.

As with Shanks and Stjohn (1994) these findings do not mandate that the underlying internal models are fully implicit and cognitively impenetrable, or that they result from a learning system that is qualitatively different from explicit learning. It is well established that participants may be able to access even highly implicit knowledge, if (1) post-experiment probes provide the same cues as the performance situation, and (2) if they tap into the same kind of knowledge as the response time task (see Shank & StJohn, 1994). Indeed, as noted, across the five experiments, there was clear evidence that participants could access these internal models to answer questions about the acting individuals – what they like and dislike, and how they typically respond in the different situations – when prompted in such a manner after the experiment. Thus, while (most) participants appear to be unable to spontaneously detect the manipulated statistical regularities to strategically control their responses, they are still able to access, in a retroactive fashion their person-knowledge after the experiment. In a similar way to artificial grammar learning (e.g., Reed & Johnson, 1994), the complex rules may not be explicitly articulated, but the output from these (e.g., knowing when a sentence is grammatically correct, or knowing which action someone typically performs in a given situation) is explicitly available.

Similar findings are available from social psychology. The explicit judgments that people make about others are typically represented separately, or abstracted away from the behaviours that were actually observed, leading to a similar lack of strong correlational relationships as observed here (Hastie & Park, 1986; Tormala & Petty, 2001; Klein, Loftus, Trafton & Fuhrman, 1992). It has, therefore, been argued that participants might not make explicit judgments during the action identification task at all. It is only when explicitly asked after the experiment, that they form such impressions in an ad-hoc manner, by relying on their (imperfect) memory of what was previously observed. Similarly, in the present experiments, the action identification effect without explicit post-hoc knowledge might, therefore, emerge because some people might be less able than others to access their memory of the observed behaviours, and may not be able to recall the differences in the individual's behaviour.

This interpretation is also in line with research on causal or statistical learning. People can learn complex second-order relationships between events, and respond faster to expected stimuli, compared to unexpected ones. Typically, this knowledge cannot be explicitly verbalised by participants and, even if they can, it is not diagnostic of the prediction effects in the response time task (e.g., Batterink et al., 2015; Shanks & Perruchet, 2002; for a critical view see Shanks & Stjohn, 1994). As argued above, this does not necessarily mean that there are two separate systems for implicit and explicit learning (unlike in the COVIS models; Ashby et al., 1998; Maddox & Ashby, 2004). Instead, it might suggest that participants solve explicit tasks by trying to re-activate their internal models based on the cues provided, but that this re-activation is imperfect and differentially effective in different individuals (e.g., Cleeremans & Destrebecqz, 2003; Jamieson & Mewhort, 2009; Shanks & Stjohn, 1994; Zaki, 2013).

Experiment 1d further supported the idea that the effects of actor identity on action identification do not reflect explicit information, showing that dissociable effects are evoked when participants are indeed given explicit information about the actors. In this experiment, participants evaluated behavioural hypotheses about the actors – that one actor might typically type, but rarely kick, or vice versa – while different blocks varied the extent to which the actors followed these patterns. Whilst statistical behavioural regularities again sped up identification times, as in previous experiments, the explicit behavioural hypotheses affected error rates, causing participants to respond according to the explicit behavioural predictions, instead of what was perceived. This finding suggests that explicit knowledge about others' typical behaviour may, therefore, induce an involuntary "social confirmation bias" towards the expected actions, irrespective of the actual behavioural patterns. This supports the previously discussed suggestion that predictions are implicitly formed through learned behavioural patterns, and then explicitly tested through “behavioural wagers” (Dale et al., 2012; Duran & Dale, 2009; Marcus et al., 2006).

The goal-directed bias

An unpredicted but robust finding was that across the ‘implicit’ experiments (1a & b) the effects of action identification were largely restricted to goal-directed actions. That is, the prediction effects present in the response times are primarily seen for the acting towards, but not the turning away trials.

One reason for this bias towards acting towards objects might be that objects provide cues to intentions (Bach et al., 2014). Whilst there are many reasons one might turn from an object (dislike for the object, boredom, attention drawn elsewhere, etc.), acting on an object implies a clear intention (Bach et al., 2014). As such, the findings are in line with the suggestion of Barresi and Moore (1996) that intentional relations are only created for goal-directed behaviours, which are diagnostic about future behaviour and underlying mental states. Objects, with their well-known functions, provide such goals that can guide action observation (for a review see Bach et al., 2014). Indeed, as aforementioned, the majority of mirror neurons (one of the proposed core nodes of action observation networks) fire for the afforded actions towards objects, but not intransitive or pantomimed actions, for example (e.g., Enticott et al., 2010; for a review see Fabbri-Destro & Rizzolatti, 2008). Similarly, several studies show that such afforded interactions with an object are perceived more easily than non-afforded actions (Bach et al., 2005; van Elk et al., 2009), and that objects and actions are “bound” together, even to the extent that visual extinction after brain lesions can be overcome

(Riddoch, Humphreys, Edwards, Baker, & Willson, 2003). The current data may, therefore, provide preliminary evidence that social prediction may act on the same action observation system, specifically predicting those actions that can be linked to such a goal.

An alternative - but related - explanation may be that the acting towards and withdrawal trials may be processed differently. For example, there is evidence that children find false belief tasks more difficult when it involves an avoidance compared to an approach goal, such as when Billy must avoid the box containing the frog, compared to when Billy must approach the box (Friedman & Leslie, 2005). Based on findings like these, Friedman and Leslie (2005 p. 222) suggest that this difficulty results from “double inhibition”. Generally, such reasoning judgments involve several potential beliefs competing, and one emerging as the ‘best’ belief via selection-by-inhibition (Friedman & Leslie, 2004). However, making an action prediction based on a desire for avoidance requires further inhibition (Leslie et al., 2005). Thus, whilst object-directed actions are easily accessible to prediction (see above), the additional processing of the avoidance stimuli could also explain the current findings of longer response times, and fewer differences, between typical and atypical withdrawals.

More than just a strategic response

One potential argument is that the prediction effects found in the current experiments may simply reflect that participants are explicitly aware of the manipulation and are making strategic responses based on this. However, the current experiments provide evidence against this explanation.

First, the dissociation between implicit and explicit knowledge suggests that the prediction effects seen are unlikely due to strategic responses because participants show the effect even when there is no evidence that they have explicit knowledge of the behavioural tendencies of the actors.

Second, the prediction effects were primarily found for goal-directed actions with objects (kicking a ball, typing on a computer), but not for withdrawals from the objects. If participants really were making strategic responses based on their explicit knowledge of actor behavioural tendencies (or had simply learned some simple stimulus response mapping) then the 'prediction effects' should have been seen across both action types equally. Thus, explicit awareness of John tending to kick the ball and turn away from the computer should lead to preparation of these responses as soon as the neutral image is shown. As such, responses times should be faster for John kicking the ball and turning from the computer, and slower when he acts differently. Instead, for all experiments without explicit instruction there was a marked facilitation for response times only when John kicks the ball compared to when he types at the computer, but these differences based on action typicality are minimal when the action is to turn away from the object irrelevant of whether it is predicted (John turns from the computer) or mismatches predictions (John turns from the ball).Yet, explicitly providing the manipulation (Experiment 1c) does result in this strategic response anticipation for both action types, and an associated effect in the error data. This effect is replicated in Experiment 1d where participants are asked to test behavioural hypotheses.

Similarly, the prediction effects were only found in response times, not error rates. Yet, if participants had just strategically anticipated the forthcoming actions, one would expect error rates to be affected as well, where participants press the incorrectly anticipated key. Indeed, in Experiment 1c where participants were given the explicit information, and in Experiment 1d, where participants were given such (valid or invalid) information about the individuals' behavioural tendencies, just such an error rate effect was observed. As explained above, explicit knowledge can enable participants to prepare their response in advance of seeing the action leading either to slower responses whilst they move to the other response button, or errors if they go too far in their preparation and actually press the button before they have realised the opposite action is being displayed.

Finally, Experiment 1e adapted the paradigm to include 'online' prediction trials whereby the participants see the neutral photographs of the actors next to the object and must say what happens next. If the previous results are due to a stimulus-response mapping, then the prediction trials should show close to, or beyond, explicit awareness levels because participants will just press the button they have learned to press with that particular stimuli. However, this is not the case. Instead, participants show better than chance, but not close to full expectancy level responses towards typical actions.

Limitations and open questions

The current series of experiments provides initial evidence that, once established, internal models of other people's behaviour are accessed fluently during action observation and bias the identification of the action towards these predictions, both when given explicitly and implicitly. However, given that this was the first foray into these processes, several questions remain unanswered.

One issue is that the variability in situations and actors in the present experiments was, necessarily, restricted. In contrast, everyday life is a much richer, more dynamic experience with many driving forces on behaviour rather than simple binary options (kick the ball or turn away from it). As such, further research needs to establish whether results generalise to real-life situations, including investigating the effects of multiple different individuals across a variety of more loosely connected, and less distinct situations. Neither social nor experimental psychology can currently provide substantial evidence to answer this question.

Linked to this, it still remains to be seen how ‘social’ such predictions really are. It may be argued that there is continuity between the learning mechanisms for physical and social causality based on similarities between the internal models one builds of other people and for physical systems (Goodman, Baker, & Tenenbaum, 2009; Meltzoff & Gopnik, 2013). It is likely that the social system ‘piggybacks’ on the physical system (see Buchsbaum, Bridgers, Skolnick Weisberg, & Gopnik, 2012; Goodman et al., 2009; Meltzoff & Gopnik, 2013). Therefore, future studies need to establish to what extent uniquely social mechanisms underlie the current effects, or whether the social biases merely guide attention towards the relevant elements in the stimulus display, such as the actor, the object, and the action which connects them. For example, in the current paradigm it may be that, rather than learning about the behavioural tendencies of the actors, participants merely learn which button to press in which situation.

Whilst not the focus of the current chapter, the findings here suggest a reliance on, at the very least, action-specific information. First, the prediction effect was seen predominantly for object-directed actions rather than withdrawals. Such findings would not be expected by abstract stimulus learning accounts where all stimulus types should be treated equally. Second, in Experiment 1d the explicit person descriptions were given in a social format which would require effortful conversion into non-social contingencies, which is counterintuitive especially given the evaluation required for these descriptions at the end of each block. Finally, there was a (weak) relation between prediction effects and post-experiment person ratings which, again, suggests social, or at least action-based, stimulus encoding.

Finally, how long-lasting are the effects? Typically, action prediction experiments tend to investigate short-term effects or are completely online just investigating RTs, but would the same results occur if the participants returned a few hours, days or weeks later? Certainly, there is some evidence that even simple priming effects can still be seen well over a decade later (Mitchell, 2006). To an extent, Chapter Four provides an exploration into this by using pre-existing knowledge to investigate person-specific action predictions. However, D.A. Smith and Graesser (1981) suggests that atypical information is more remembered during short testing times, but over longer periods of time, typical information is more remembered (though this is based on person-memory research, which typically tests more abstract information). Thus, future research should explore these memory effects using the more concrete actions typical of action prediction paradigms to compare the two ends of the behavioural hierarchy.

Conclusion

Five experiments demonstrated that observers routinely access ‘learned’ knowledge about the behavioural tendencies of individual actors across two situations to predict their forthcoming actions. This effect seemed to rely on largely implicit and automatic mechanisms; despite participants being unable to verbalise the underlying behaviour patterns, they formed person-specific knowledge about the individuals’ behavioural tendencies, which were observable in response times.

These data provide first evidence for a person-specific Social Prediction System, which tracks the intentional relations that others exhibit towards the environment, and uses them to predict their forthcoming actions. The data are consistent with the idea that action identification – as measured by response times and error rates here – emerges from an interaction of bottom-up cues and such top-down expectations derived from prior knowledge about the individuals.

In addition, the data suggest that humans learn about the action tendencies of others in a similar manner as they learn about the causal structure of the non-social world (Gopnik et al., 2004). Highly implicit learning mechanisms have been described that allow people to use complex algorithms or rules in a procedural manner without being able to articulate them (e.g., Day & Goldstone, 2011). The current data suggests that behavioural tendencies of others are derived in a similar manner, and may allow one to conceptually link social perception to other fields of implicit learning and tacit knowledge, such as the rules of complex sequences (Nissen & Bullemer, 1987) or artificial grammars (Reber, 1967). The current data suggests that, in a similar manner, people implicitly track the relationship between interaction partners, objects, and their most likely behaviours, to predict their forthcoming actions. Actions that match these expectations can be processed effectively, while deviations are “flagged up” and attract cognitive resources, such that one’s preconceptions can be revised or their behaviour re-interpreted (A. Clark, 2013).

Chapter Three – person-specific internal models vs. stimulus-response learning

Chapter Two demonstrated the use of person-specific internal models for action observation, which were re-activated when the same individual was re-encountered in the same situation. Action identification was faster when actors acted upon an object they typically acted upon compared to an object that was typically acted upon by the other actor. Thus, participants learned how actors tended to behave, and predicted this action would occur when the actors were encountered in that situation again. Several different tests for explicit knowledge indicated at least a partial dissociation between implicit and explicit knowledge of these person-models. These findings support the predictive coding viewpoint (e.g., Bubic et al., 2010; A. Clark, 2013; den Ouden et al., 2012; Friston & Kiebel, 2009) that perception is influenced by predictions based on prior knowledge, and reveals such an influence for knowledge about the actor's prior behaviour.

One outstanding question is whether the findings really are evidencing prediction of forthcoming action rather than mere stimulus-response learning. For example, rather than participants learning the behavioural tendencies of the actors, they could simply be learning to associate the stimuli with a specific button press. Whilst, the previous chapter details some aspects of the findings that make the latter explanation less likely, the current chapter aimed to more directly investigate this alternative explanation for the data with two different methods. First, Experiment 2a additionally recorded event related potentials (ERPs) to provide evidence for underlying components typically seen in prediction (e.g., P3b) and action error monitoring/prediction errors (e.g., N2/oERN; observer error related negativity), which would not be the expected neuronal pattern based on a simple stimulus-response bias or motor learning explanation. Second, Experiment 2b investigated whether verbal intentions for action associated to each actor in a given situation (e.g., “Yeah, I’ll have a go”, “Nah, I’ll leave it”) transferred to action identification causing prediction effects, even when their actual behaviour does not show any such pattern. Evidence for such transference would provide evidence that the effects result from learning the ‘meaning’ of the actions (i.e., the behavioural tendencies of the actors), rather than simple stimulus or motor learning. Yet, if the previous data merely reflect motor learning/a stimulus-response bias then the verbal information should not influence action identification because participants would simply be learning which stimuli are associated with which button press. As such, any evidence that this verbal information influences action identification would provide further support for a predictive coding explanation for the prior effects.

Experiment 2a: The underlying neural components involved in social action predictions

Experiment 2a was primarily conducted to, first, provide further evidence for a prediction effect of actions rather than mere stimulus-response learning and, second, to investigate the underlying neural networks involved in creating and reactivating person-models for action observation using electroencephalography (EEG). The key components implicated in such a predictive coding mechanism are P3b and N2/(o)ERN.

The P300 component - a positive deflection typically seen between 250 and 500 ms - is thought to be involved in attentional resources, reallocating attention and memory, and evaluating and updating representations (for a review see Polich, 2007). One of its components, P3b, primarily originating in the parietal lobe (see A. Kok, 1997; Polich, 2007), is thought to be involved in integrating top-down and bottom-up processing, as well as attentional processing. For example, P3b activation is larger for unexpected compared to expected stimuli (Balconi & Canavesio, 2015). This supports the context updating hypothesis commonly associated with the P3 component i.e., that it represents the revision of a hypothesis (Donchin & Coles, 1988; Duncan-Johnson & Donchin, 1982) and, more recently, that P3b is thought to reflect a behavioural adjustment based on explicit rules (Chase, Swainson, Durham, Benham, & Cools, 2011).

The N2 component - a negative deflection typically seen between 200 and 350 ms post-stimulus - is thought to primarily originate from the anterior cingulate cortex (ACC; for a review see Folstein & Van Petten, 2008). Both the N2 and ACC are typically activated during conflict resolution, and are commonly linked to processing prediction errors (N2; Kopp, Mattler, Goertz, & Rist, 1996; Van Veen & Carter, 2002, ACC in rats; Bryden, Johnson, Tobia, Kashtelyan, & Roesch, 2011, ACC in humans; for a brief review see Bush, Luu, & Posner, 2000).

A larger negative ERP ("oddball" N2) has been demonstrated both for low probability action effects, as well as when more conflict is present (Azizian, Freitas, Parvaz, & Squires, 2006; Band, van Steenbergen, Ridderinkhof, Falkenstein, & Hommel, 2009). This supports predictive coding assumptions (e.g., Bubic et al., 2010; A. Clark, 2013; den Ouden et al., 2012; Friston & Kiebel, 2009) of increased processing when predictions mismatch reality. Furthermore, N2 may indicate a cue for subsequent goal-directed processes (Dockree, Kelly, Robertson, Reilly, & Foxe, 2005), and has been suggested to indicate detection of, or inhibition of, inappropriate responses (Kopp et al., 1996). This would explain why N2 and P3b often coincide in the N2-P3b complex - N2 represents the detection of an error, and P3b represents the subsequent updating of the hypothesis. Indeed, Knolle, Schröger, and Kotz (2013) have shown increased N2 and P3b activation indicative of prediction errors and updating respectively in relation to self-generated sounds.

N2 and feedback ERN – negative activation which typically follows negative feedback, such as after an action error, on a task – have a large overlap, which research has yet to satisfactorily separate, and which are sometimes argued to reflect the same component (see Holroyd, 2004). The ERN, which, as its name suggests, is heavily involved in error detection, is also thought to stem from the ACC (for a review see Walsh & Anderson, 2012; see also Bush et al., 2000). The ERN is thought to be reflective of a generic error-detection mechanism, which can relate to different types of errors (time, action, choice, etc.) depending on task goals (Miltner, Braun, & Coles, 1997).

An early negative fronto-central activation indicative of ERN has recently been suggested to reflect an action prediction error (Balconi & Canavesio, 2015). Specifically, the ERN has been suggested to compare actual responses with representations of the correct response (Bush et al., 2000). Moreover, the ERN tends to be larger when correct and incorrect responses are very similar (Gehring & Fencsik, 2001). This supports the frequent attribution that the ACC anticipates cognitively demanding tasks (Bush et al., 2000). From a predictive coding viewpoint, this increased activation when predictions closely mismatch reality reflects the increased precision (and thereby attention or cognitive resources) needed to detect such mismatches. Indeed, the ACC has also been found to receive feedback in decision-making tasks (Bush et al., 2002), and to signal conflicts to higher-level areas for example the lateral prefrontal cortex, (J. D. Cohen, Botvinick, & Carter, 2000) and the basal ganglia (Falkenstein et al., 2001; for a review see Van Veen & Carter, 2002).

Such views fit well with the general role of the medial prefrontal cortex (mPFC), particularly the ACC, in performance monitoring predominantly to adjust high level goals (e.g., Bush et al., 2000). Moreover, Oliveira, McDonald, and Goodman (2007) demonstrated that the ACC could be seen as a more general performance monitoring system, rather than mere error detection and poor performance evaluation. The recent Predicted Response Outcome (PRO) model by Alexander and Brown (2012) implicates the mPFC, and specifically the ACC, as a learning centre heavily involved in action outcome predictions. Accordingly, the mPFC learns to predict action outcomes, and compares actual and predicted outcomes irrelevant of the valence of the outcome (rewarding or aversive). Crucially, in line with Chapter Two, the PRO model is more concerned with mapping existing action plans into the stimulus context to predict outcomes and responses, rather than being for stimulus-response mappings per se. Multiple outcomes can be assessed simultaneously and are given a probability. Discrepancies result in a prediction error, which is used to update future predictions (for a similar model for signed prediction errors see Silvetti, Seurinck, & Verguts, 2011).

Whilst much previous research focused on the ERN as a monitor for own action errors, recent evidence has demonstrated its activation during the observation of others' errors (observer ERN; oERN). For example, van Schie, Mars, Coles, and Bekkering (2004) found evidence of the ERN for own and observed action errors, with very similar scalp distributions, supporting the theory that a similar neural mechanism is involved in monitoring both executed and observed actions. This oERN began around 90 ms after the error, and peaked around 250 ms. Similarly, Kobza and Bellebaum (2013) presented participants with an actor playing a game whereby participants had to select the correct box that a pea was hidden in. In some trials, the pea was moved without the observed actor knowing and thus enabled manipulation of what the participants expected the actor to choose. They found greater negative fronto-central activation for unexpected compared to expected actions, thus suggesting oERN reflects an action prediction error with the ACC monitoring predictions. Similar findings are also found for error-related negativity found after negative feedback to a stimulus (feedback-related negativity; FRN). For example, Koban, Pourtois, Bediou, and Vuilleumier (2012) found an increased FRN, and related P3b activation, for both own and observer actions (observer feedback-related negativity; oFRN) for unpredicted compared to predicted stimuli.

Interestingly, there is some evidence to suggest a social modulation of both the oERN and oFRN activation. For example, Carp, Halenar, Quandt, Sklar, and Compton (2009) found evidence for an oERN and related positivity (oPe) during a flanker task, but, interestingly, this was modulated by how similar the observer felt in relation to the observed. Higher interpersonal similarity was related to a larger oPe, but smaller oERN suggesting the influence of social factors in this error monitoring of observed behaviours. Similarly, activation of the ACC (where the ERN is thought to originate from) is modulated by observer empathy and liking for the observed; ACC activation towards others pain was higher for those with higher empathy, or when liking for the observer was higher (for a brief review see Singer, 2006). Similarly, the oFRN had smaller amplitudes for competitive rather than cooperative observers. The source of these FRNs and oFRNs were estimated to be in the mPFC (with additional activity in dorsolateral and ventral PFC for oFRN).

These ‘observer’ error- and feedback-related negativity components provide evidence for an overlap in the framework for action prediction for own and others’ actions (see Chapter One). This is in line with the notion that mirror neurons fire both during action execution and action observation (e.g., di Pellegrino et al., 1992; Rizzolatti, Fadiga, Gallese, & Fogassi, 1996), and during action prediction (Lamm, Fischer, & Decety, 2007) and monitoring (Bach et al., 2014).

In terms of the hypothesised person-models, a review by Lavin et al. (2013) supports a context and agent specific centre within the ACC for high level processing of other people (though here agent was assessed by an in-group/out-group differentiation rather than individual specificity per se.). More recently, Welborn and Lieberman (2014) demonstrated evidence of person-specific Theory of Mind via increased activation of the mPFC for more well-known than lesser-known politicians. Taken together, these studies highlight the mPFC as a centre for processing person-knowledge. Indeed, when trying to understand others, the mPFC, superior temporal sulcus (STS), orbitofrontal cortex (OFC), amygdala and anterior insula form a network of activation (C. D. Frith & U. Frith, 2006). Thus, the mPFC is likely to be heavily involved in the creation and use of person-models, particularly in relation to updating these models. Indeed, the ACC has been shown to be involved in transforming intentions to actions, and to align errors with goals (Holroyd, Nieuwenhuis, Mars, & Coles, 2004).

The current experiment replicated the prior behavioural work of Chapter Two whilst additionally measuring ERPs. It was, therefore, hypothesised, in line with the predictive coding evidence described above, that there would be evidence for both the P3b and oERN during atypical actions towards objects. Specifically, it was hypothesised that the P3b component would be more positive for the atypical compared to typical trials, in line with previous research suggesting that the P3b is more active for prediction errors than correct predictions (updating internal models based on actual events; see Donchin & Coles, 1988; Duncan-Johnson & Donchin, 1982). Crucially, however, if the prediction effects for the acting towards trials reflect attribution of goal-directed action, and if oERN reflects monitoring of such actions of other people, the oERN should primarily be found in the act towards rather than turn away trials. This would support numerous experiments demonstrating that only goal-directed actions activate the mirror system (e.g., Agnew et al., 2012; Enticott et al., 2010; for a review see Fabbri-Destro & Rizzolatti, 2008), and Barresi and Moore's (1996) notion that intentional relations between people, actions and situations are only established for goal-directed behaviours. Indeed, previous studies have found that afforded interactions with an object are perceived and predicted more readily than non-afforded interactions (Bach et al., 2005;

van Elk et al., 2009), and that action predictions occur for meaningful actions towards objects (Hunnius & Bekkering, 2010; Stapel et al., 2012), but not for avoiding an object, which is more likely to be coded as an inhibition of a potential approach (Friedman & Leslie, 2005; Leslie et al., 2005). Thus, the current hypotheses are in line with these studies (and those in Chapter Two) which suggest a 'special status' for object-directed actions during action prediction.

Method

Participants

Thirty-one participants (21 females, mean age = 21.00 years, SD = 1.68 years; all right handed based on the Edinburgh Handedness Inventory) took part in the study in exchange for £16 or course credit. None had any history of neurological impairment and all reported having normal, or corrected-to-normal, vision. One participant was unable to continue due to technical difficulties, and two further participants reported awareness of the relevant manipulation in the funnel debrief so their data was not analysed further. Due to excessive eye and muscle movement artefacts (> 30% of the data), the data from one additional participant was removed.

Materials, apparatus and procedure

Two questionnaires were administered whilst the electrodes were being applied. The empathy quotient (Baron-Cohen & Wheelwright, 2004) consisted of sixty statements such as "I can easily tell if someone else wants to enter a conversation" and "I prefer animals to humans" that participants could either "strongly agree", "slightly agree", "slightly disagree" or "strongly disagree" with on a 4-point Likert scale. To assess potential correlations with schizophrenic characteristics, the O Life questionnaire (Mason, Linney, & Claridge, 2005), measuring dimensions of schizotypy was administered. This questionnaire consisted of 43 statements such as “When in the dark do you often see shapes and forms even though there is nothing there?” and “Are you easily confused if too much happens at the same time?” to which participants had to respond either “yes” or “no”. However, there were no significant correlations between the prediction effect and either of these two questionnaires, so neither will be discussed further.

Once the electrodes were in place, the participants then completed the computer task which contained 340 trials (20 practice trials and 320 critical trials), and was controlled by E-Prime 2.0 (Psychology Software Tools, Pittsburgh, PA). The computer task was identical to Experiment 1b except that correct responses were followed by a screen indicating that participants could blink “(-)(-)” without affecting the ERP data. Incorrect (or missed) responses were followed by a reminder of the task.

Participants then completed the two exit questionnaires, as in the previous experiments.

EEG recording and analyses

Scalp voltages from 64 Ag/AgCl active electrodes (ActiCAP, Brain Products GmbH) were recorded using BrainVision Recorder (Version 1.10, Brain Products GmbH), configured according to the International 10-20 system, and mounted on an elastic cap (ActiCAP, Brain Products, Gilching Germany). A further two sensors (one below the eye and another at the corner of the eye) monitored eye movements. Electrodes were referenced to the left mastoid and re-referenced offline to the average of the left and right mastoid activity. An electrode at the AFz location provided a ground. Measurements of scalp electrode impedance were kept below 20kΩ. EEG data was amplified using a BrainAmp amplifier (Brain Products), continuously sampled at 2500 Hz. Offline the sampling rate was reduced to 200 Hz, and the data was filtered with a notch filter of 50 Hz, and a band-pass filter from 0.1- 40 Hz.

For analysis, EEGs were time-locked to the onset of the second image (the image of the action), such that individual participant EEG data was divided into segments, each containing brain responses from the baseline (200 ms *before* the action image was presented) to 600 ms. This time window was chosen rather than an earlier time during the fixation point because the neutral image was always the same whether an act towards or turn away action was later observed. As such, participants could create the expectation of which action type (act towards, turn away) is more likely for this actor. However, due to the fully crossed design, the hypothesis-relevant main effect of expectancy (actor acts as expected, acts unexpectedly) cannot be affected by the neutral image as this would not provide violation to any prediction the participants may have. In other words, the neutral image simply showed the actor stood or sat with an object. Thus, whilst participants may start to predict what they think will happen, we cannot directly measure this because we do not yet have an 'error' for this prediction – this can only be measured once the actor has performed an action. Additionally, the EEG waveforms overlap directly with one another in the early components before the effects of interest, ruling out artefacts introduced through baselining (see Figures 3.5 and 3.7). Moreover, moving the baseline further away from the effects of interest would increase the signal-to-noise ratio, which would reduce power. Further grouping of these segments occurred according to trial type (acting towards typical, acting towards atypical, turning away typical, turning away atypical).

Data was discarded if the electrodes monitoring eye movement demonstrated a voltage change above 50 μv/200 ms, if any other electrodes showed a voltage change of more than 250 Hz, or exceeded a value of ±100 μv relative to the baseline. Further segments were discarded if the incorrect response was given in the trial. Finally, ERPs were computed by averaging artefact-free EEGs (~80% = 7638 trials).

Differences in waveforms across conditions were analysed using the Monte Carlo cluster randomisation analysis procedure designed to eliminate the multiple comparisons problem (Maris & Oostenveld, 2007). Here, individual paired sample t tests at each time sample identified significant differences at an alpha level of .05. Then, clusters containing a minimum of 20 samples (from 80 ms up to 600 ms) were identified based on significant t tests that were contiguous across time at adjacent locations (within 4mm of each other). Finally, a cluster-level t value was computed based on the sum of all single sample t values within each cluster. It was this t value for each of the 16 clusters that was used for subsequent analysis rather than using the individual (highly non-independent) t values.

To ascertain significance of these clusters, comparisons against a standard t distribution would not be reliable, so each t value was, instead, compared to a Monte Carlo distribution of cluster level t-values. This distribution contained the cluster with the largest t value to control the false alarm rate for all clusters at the expense of sensitivity for the smaller clusters (Maris & Oostenveld, 2007).

The original paired samples t tests were repeated, but the data items were randomly assigned between the conditions. This was performed 1,000 times to generate a Monte Carlo distribution of 1,000 summed t-values corresponding to the null hypothesis. This provided a null distribution for comparison with the actual cluster-level t statistic of each of the observed clusters. Therefore, a Monte-Carlo *p* value was generated for each observed cluster, in proportion of the null distribution, which had a cluster-level t statistic that exceeded the actual cluster-level t-statistic.

Results

Behavioural data

Funnel debrief

The average overall ease of the task was perceived to be 7.00 (out of 10). The data suggested that the actors and the actions/objects were equally salient with neither being easier to identify conclusively (see Table 3.1).

Table 3.1:

Data showing which actor and action participants rated as easier to identify for Experiment 2a

Character	Easiest to identify	Action	Easiest to identify
Claire	9	**Ball/kick**	13
John	5	**Computer/type**	8
Neither Claire nor John	16	**Turning away from an object**	2
		None	7

Twenty-nine participants (93.55%) did not notice anything unusual in the stimuli, Twenty-three participants (74.19%) said they did not notice a pattern, and the rest mentioned similar proposed patterns as in previous experiments. As mentioned above, two participants (6.45%) mentioned the manipulation and were removed from analysis.

Response times

The same exclusion criteria as in Chapter Two were applied, with 4.76% of trials being excluded in total (3.42% for error trials, 1.34% for scores greater than 3 SD from the mean). The remaining data were analysed with a repeated measures ANOVA with the factors Observed Action (act towards, turn away) and Action Typicality (typical, oddball).

The analysis revealed a significant main effect of Observed Action, $F[1,27] = 13.379$, $p = .001$, $\eta\rho^2 = .331$ with faster response times for actions towards ($M = 414.34$, $SE = 17.71$) than away ($M = 438.44$, $SE = 15.87$) from objects. There was also a significant main effect of Action Typicality, $F[1,27] = 25.853$, $p < .0.001$, $\eta\rho^2 = .489$, with faster response times for typical ($M = 418.511$, $SE = 15.93$) than atypical ($M = 434.27$, $SE = 17.17$) actions. Importantly, replicating the studies from Chapter Two, this main effect was further qualified by a significant interaction between both factors, $F[1,27] = 15.161$, $p = .001$, $\eta\rho^2 = .360$. As before, the prediction effect was larger for actions towards objects compared to turns away from objects. However, as can be seen in Figure 3.1, actions were identified more rapidly when they were typical compared to atypical for the actor for both the acting towards ($t[27] = 5.901$, $p < .001$, $d = .25$) and turning away trials ($t[27] = 2.406$, $p = .023$, $d =.10$).

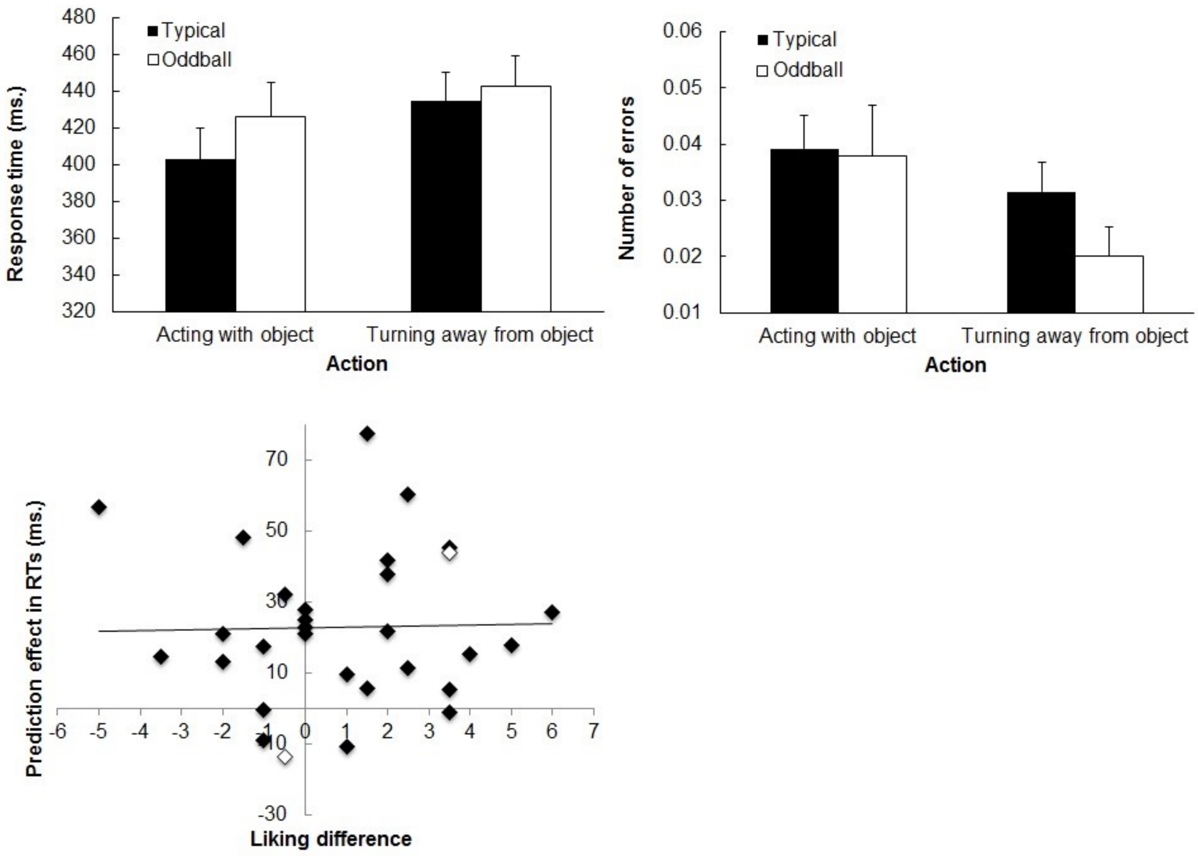

Figure 3.1. Response time and exit questionnaire data for Experiment 2a
The top left panel shows the average response times, and the top right panel shows the average proportion of errors. In each panel, the left bars show identification of actions towards objects (typing on a computer or kicking the football), and the right bar shows actions away from objects (turning away from the same objects). The black bars reflect actions typical of this individual in the given situation, and the white bars show the action typical of the other individual. Error bars show the standard error of the mean. The bottom panel shows a correlation between prediction effects in the RTs for actions towards objects and the corresponding differences in perceived object liking, for individuals who either identified (*unfilled diamonds*) or did not identify (*filled diamonds*) the behavioural pattern.

Errors

Error data were analysed with the same ANOVA. The analysis revealed a main effect of Observed Action, *F*[1,27] = 4.799, *p* = .037, $\eta\rho^2 = .151$ with higher error rates for actions towards (*M* = 0.039, *SE* = .006) than away from objects (*M* = 0.026, *SE* = .005), but there was no main effect of Action Typicality, nor an interaction between these two factors (both *F* < 1.542).

Liking

When the objects were typically acted upon they were rated as more liked by the relevant actor (*M* = 1.46, *SD* = 1.50) than when they were turned away from (*M* = 0.52, *SD* = 1.70), which reached borderline statistical significance, *t*[27] = 1.958, *p* = .061, *d* = 0.59. Again, regression analyses tested whether this explicit awareness predicted the effects during action identification. There was no significant correlation (*r* = -.048, *n* = 28, *p* = .999) between these factors, but the intercept was significantly different from zero (*t* = 5.563*, p* < .001) indicating that, as in Chapter Two, even those participants with no apparent explicit awareness in the liking ratings still showed significant prediction effects in the response times.

ERP data

Analyses were performed for the factors Action Typicality (typical, oddball) and the interaction between Action Typicality and Observed Action. The Bonferroni-corrected alpha level for all the ERP data based on the cluster analyses was .025 (see Maris & Oostenveld, 2007).

For the main effect of action typicality, there was one significant cluster that survived cluster correction (see Figure 3.2) approximately between 440 and 600 ms post onset of the action stimulus (*p* < .001). There was greater positive activation in central, parietal and occipital regions for the atypical compared to typical trials. This is indicative of the P3b component, which is thought to involve updating of situation models during unexpected events (see Polich, 2007).

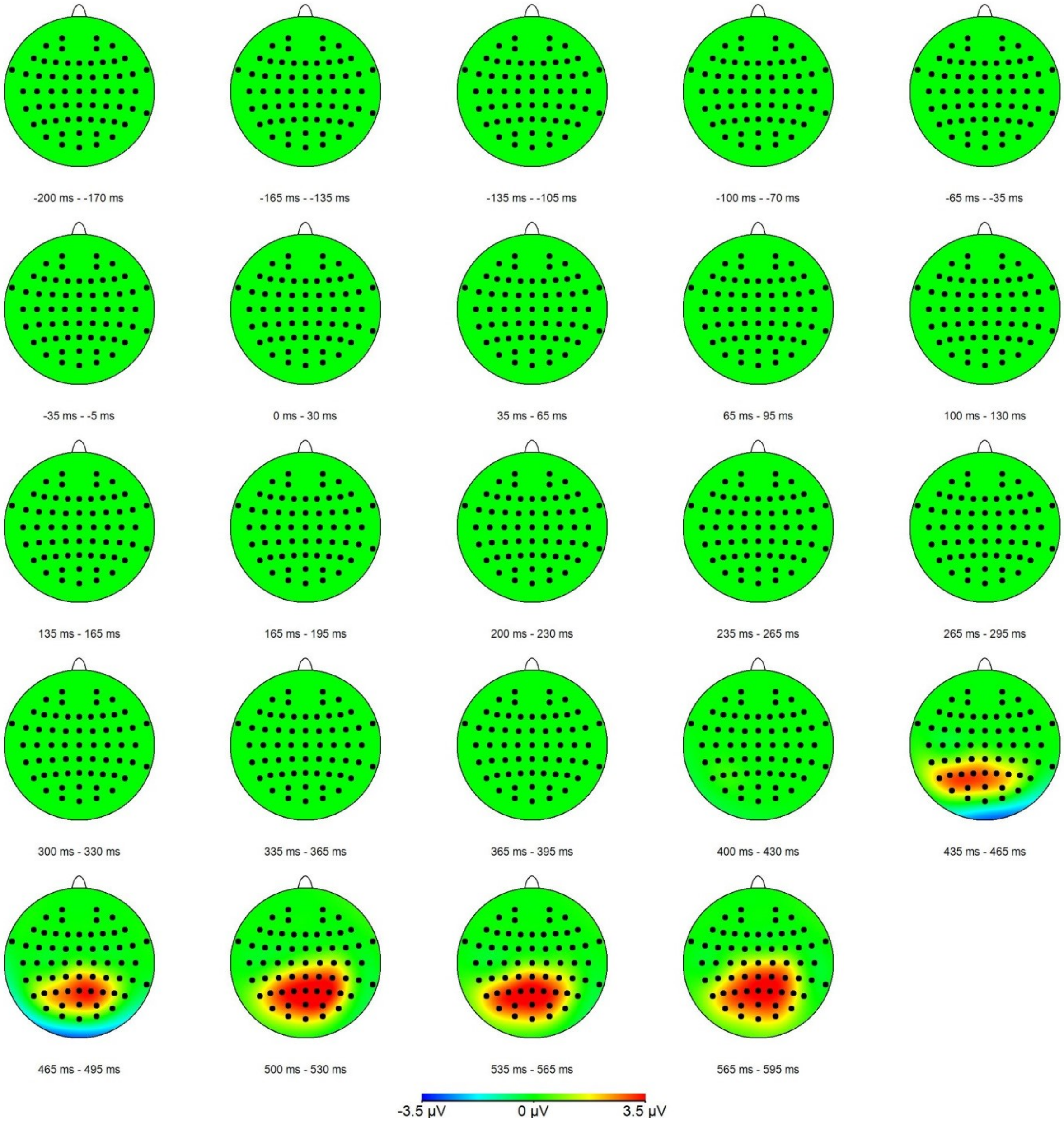

Figure 3.2. ERP data for the main effect of Action Typicality
Mean averaged activation between 100-600 ms post-stimulus for the main effect of Action Typicality showing only clusters that survive thresholding with Monte Carlo analyses

The analysis of the interaction between Observed Action and Action Typicality revealed two significant clusters that survived the cluster threshold (see Figure 4.3). The first was found approximately around 200-320 ms post action onset in the left frontal region (*p* = .008). Here, interactions towards objects elicited larger inflections when performed by an actor for whom this action was atypical, compared to an actor for whom it was typical. This is indicative of either the N2 component or the oERN. The second cluster occurred between approximately 540-600 ms within the frontal region ($p < .001$). This is indicative of the P3b component, and thus of the model updating process. The data reflects that, in this time interval, unexpected events elicited larger negative inflections for actions towards compared to away from the objects.

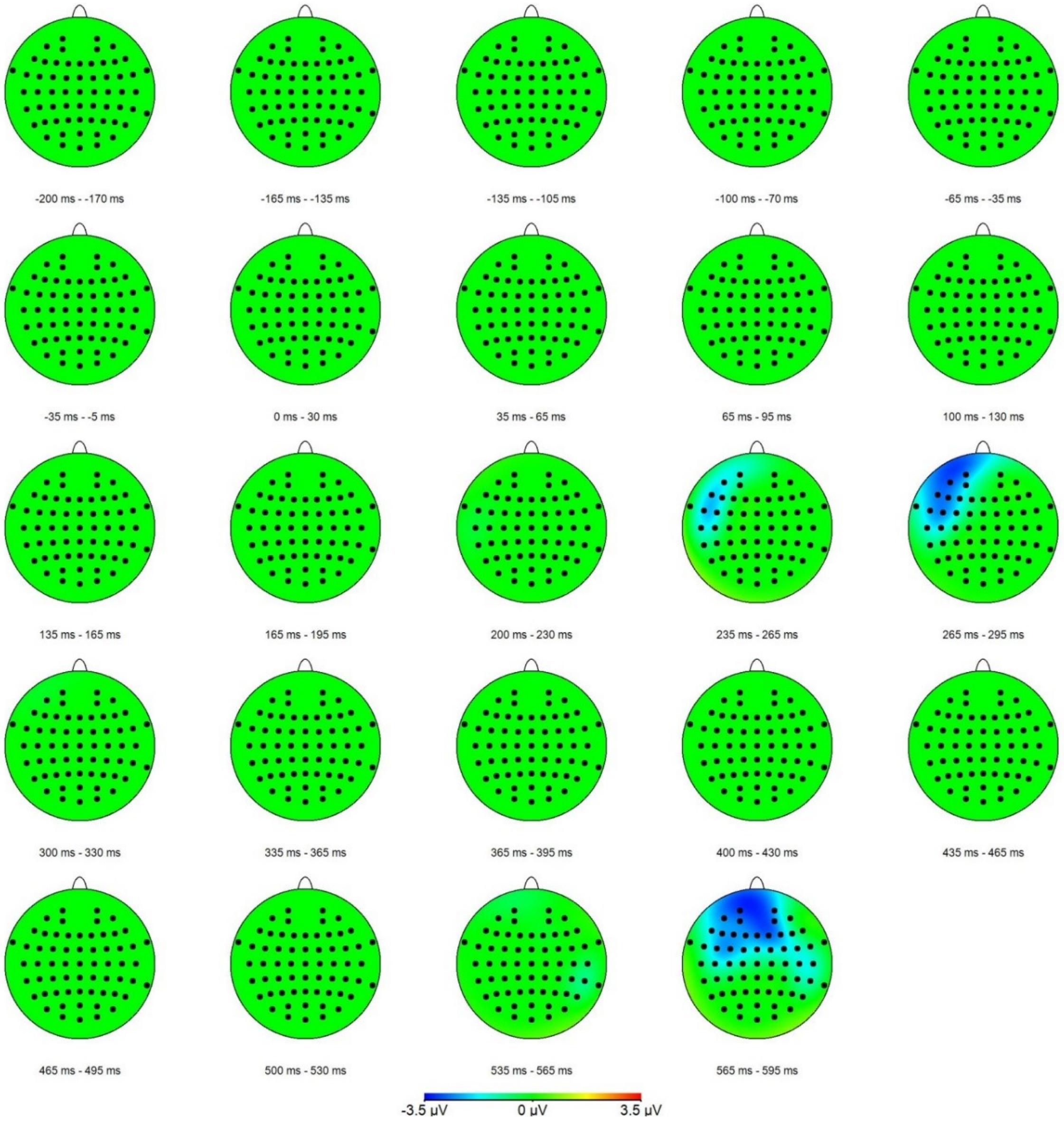

Figure 3.3. ERP data for the interaction between Action Typicality and Observed Action
Mean averaged activation between 100-600 ms post-stimulus for the interaction between Observed Action and Action Typicality showing only clusters that survive thresholding with Monte Carlo analyses

Planned comparisons were conducted on the acting towards and turning away trials separately. For the acting towards trials, there were two significant clusters (see Figure 4.4). The first occurred approximately around 200-320 ms (*p* = .006) in the left frontal and central regions, thereby coinciding with the first cluster in the analysis of the interaction between Action Typicality and Observed Action. There was greater negative activation in these areas for atypical compared to typical trials indicative of the N2/oERN component. The second cluster occurred approximately around 440-600 ms (*p* = .001) within central and parietal regions. There was greater positive activation in these areas for atypical compared to typical trials indicative of the P3b component.

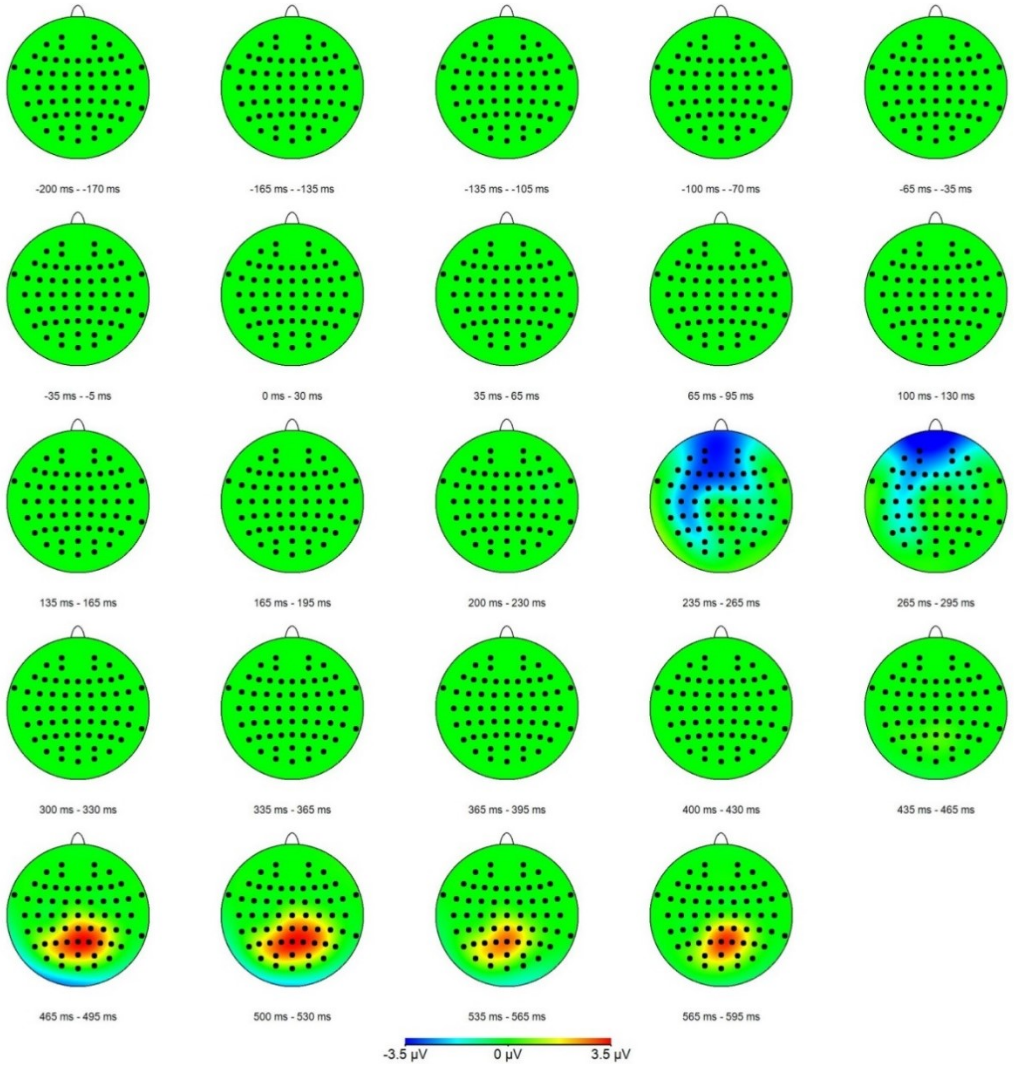

Figure 3.4. ERP data for the acting towards trials
Mean averaged activation between 100-600 ms post-stimulus for atypical compared to typical actions for the acting towards trials showing only clusters that survive thresholding with Monte Carlo analyses

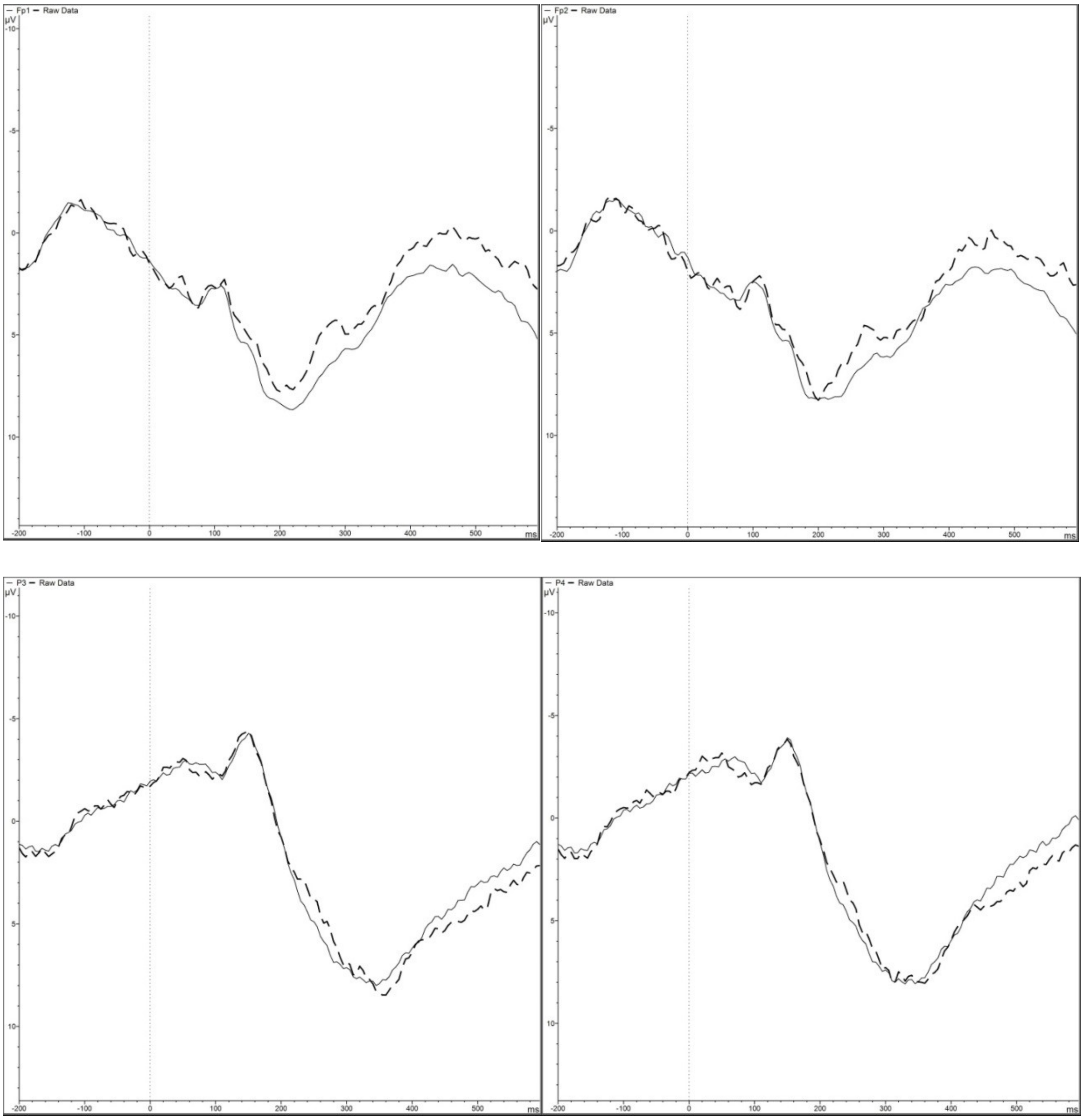

Figure 3.5*. *Waveforms for the acting towards trials
Grand averaged waveforms for actions towards objects at electrodes FP1 (*top left*), FP2 (*top, right*), P3 (*bottom, left*) and P4 (*bottom, right*). Solid lines represent typical actions, dashed lines represent atypical actions

For the turning away trials, however, there was only one significant cluster (see Figure 4.6) at approximately 320-600 ms ($p < .001$) in frontal, central, parietal and occipital regions. There was greater positive activation in these areas for atypical compared to typical trials indicative of a delayed P3b component. It coincided with the P3b difference revealed by the interaction analysis, showing that the P3b is stronger for turns away from, rather than actions towards, objects.

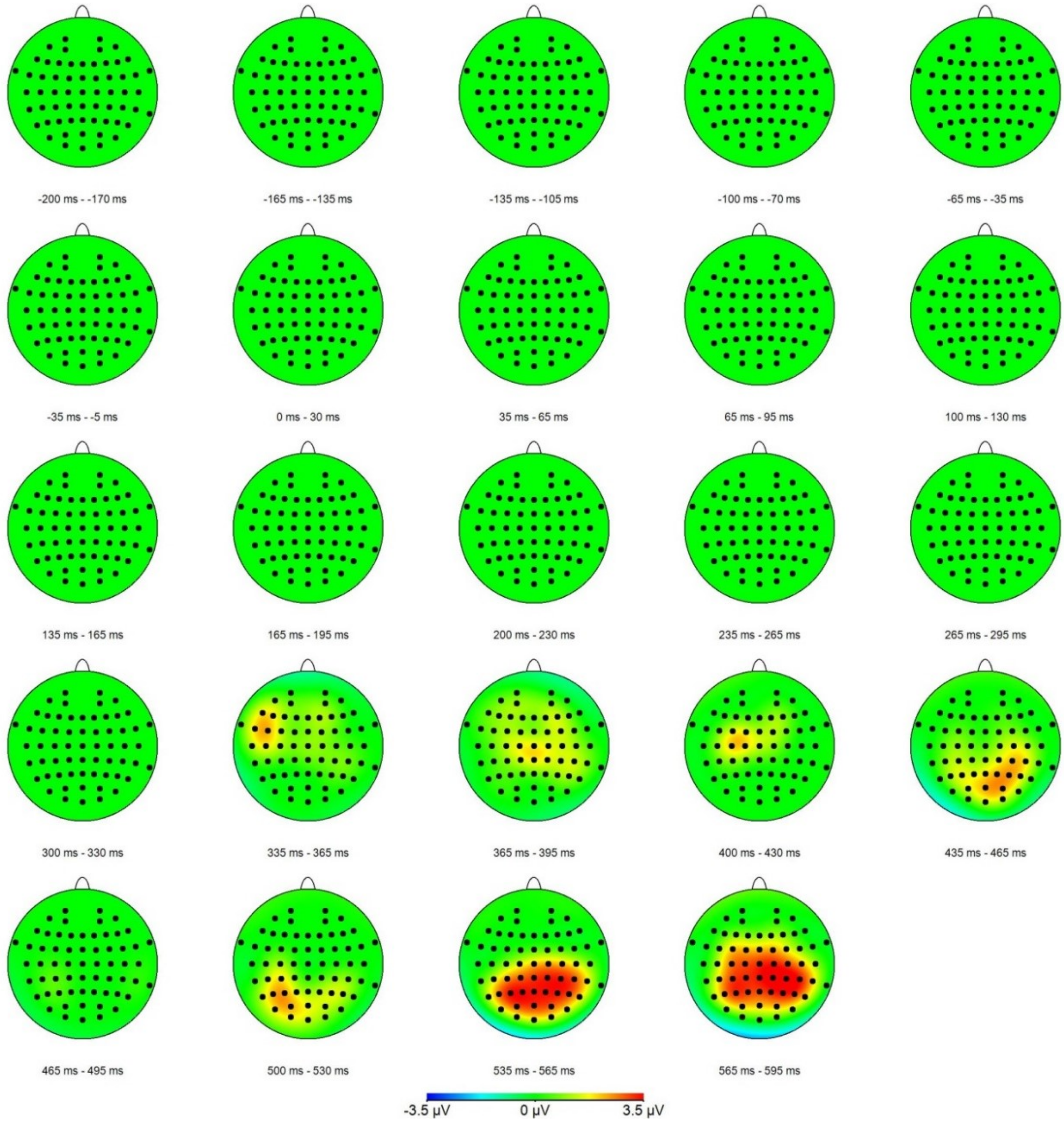

Figure 3.6. ERP data for the turning away trials
Mean averaged activation between 100-600 ms post-stimulus for atypical compared to typical actions for the turning away trials showing only clusters that survive thresholding with Monte Carlo analyses

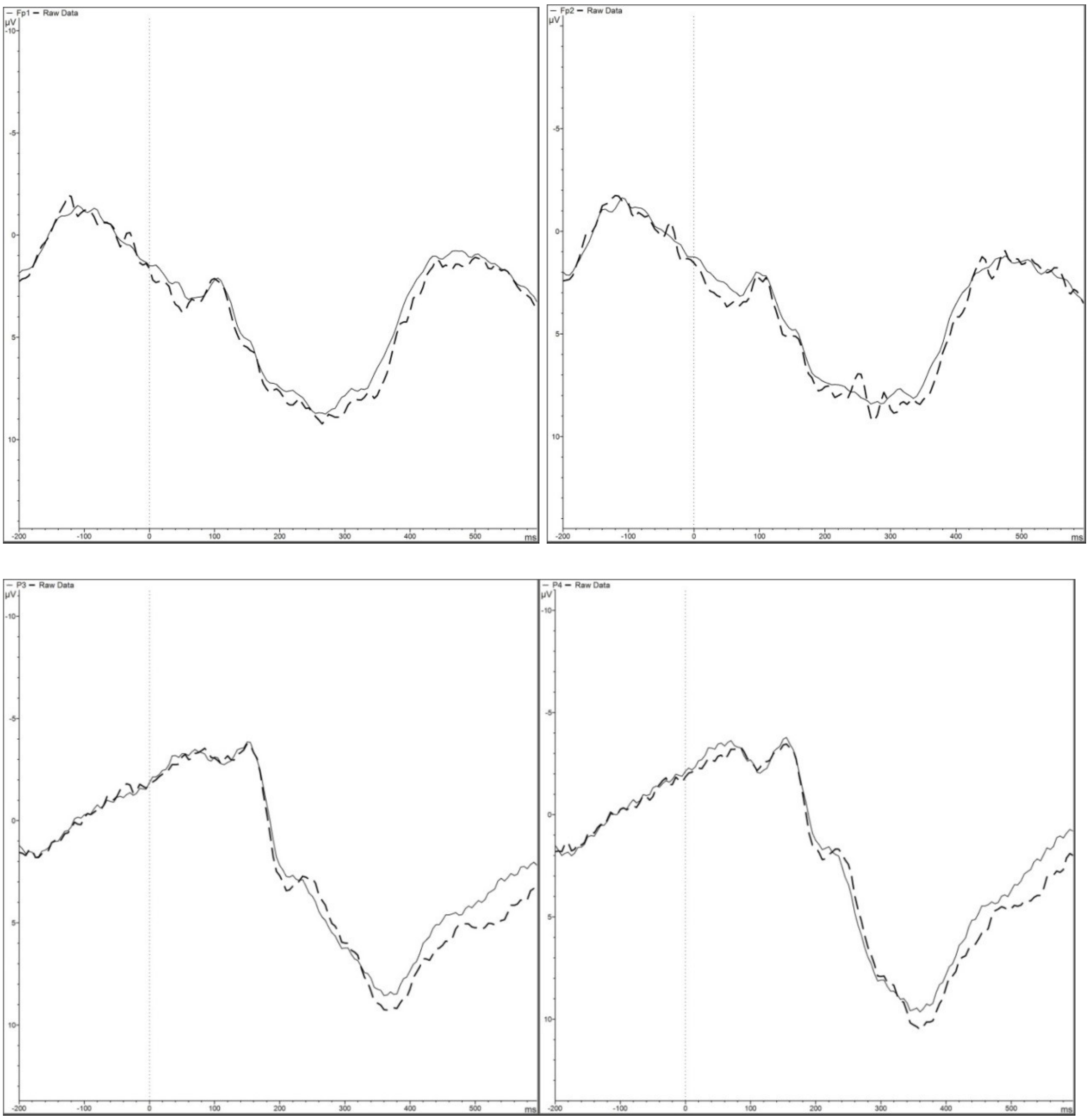

Figure 3.7. Waveforms for the turning away trials
Grand averaged waveforms for turning away from objects at electrodes FP1 (*top left*), FP2 (*top, right*), P3 (*bottom, left*) and P4 (*bottom, right*). Solid lines represent typical actions, dashed lines represent atypical actions.

Discussion

Experiment 2a aimed to replicate the prediction effect for typical compared to atypical actions seen in Chapter Two, and provide an initial test of the underlying components involved in action predictions based on an actors' prior behaviour. The behavioural data replicated Chapter Two indicating that person-specific internal models are created and re-activated when the actor is re-encountered in the given situation, even though actor identity was fully task-irrelevant. The data therefore provide further support for ‘intentional relations’ between people and situations for goal-directed behaviours (Barresi & Moore, 1996). Again, the resulting response time bias was, at least partially, dissociated from explicit ability to respond to the liking questions using information from the models post hoc.

Crucially, Experiment 2a provided clear evidence against this prediction effect reflecting simple stimulus-response learning, or general perceptual learning, which would apply to both stimulus classes – actions towards and away from objects - equally. As predicted, there were fundamental differences between the ERPs for typical than atypical actions, and actions towards and away from objects, which should not have been seen if the results stemmed from such general response biases.

As is common in oddball tasks, there was evidence for the P3b component for unexpected actions. Irrelevant of whether an action towards or away from an object was observed, greater positive activation in tempero-parietal areas was seen when the action was atypical for the actor in that situation. As P3b is typically attributed to decision-making and evaluation of a stimulus (for a review see Polich, 2007), and revising/updating hypotheses (Donchin & Coles, 1988; Duncan-Johnson & Donchin, 1982), this indicates that during these atypical trials, information was being updated or added to the internal models in the event of mismatching predictions.

Interestingly, and as predicted, there was evidence of an early negative activation in frontal regions, but only in the acting towards trials. This activation could be the N2 component but, more likely, it is evidence of the oERN component, which is frequently seen when observing actors making errors (Bismark et al., 2013; Carp et al., 2009; Koban et al., 2012; Kobza & Bellebaum, 2013; van Schie et al., 2004). This activation was greater for atypical actions suggesting that participants code the atypical action as an action error for that actor, and this information is then used to update the person-model (demonstrated by the later P3b activation).

The frontal location of the oERN indicates ACC and mPFC activity, which is heavily associated with both conflict monitoring, and integration of top-down and bottom-up information (e.g., Bush et al., 2000; Folstein & Van Petten, 2008). Such activation is also supportive of Welborn and Lieberman's (2014) assertion that this region is heavily involved in person-specific encoding.

In contrast, for the turning away trials, only the later positive activation (P3b) was seen, which was, in fact, larger than for unexpected actions towards objects. This suggests that the participants are not processing the atypical turn away as an action error as such. This may be because participants process the act toward and turn away trials in a fundamentally different way. This would support the assumptions that intentional relations are only formed (Barresi & Moore, 1996), and mirror neuron firing (e.g., Enticott et al., 2010) only occurs, for goal-directed behaviours. It also supports the conclusion in prior chapters that the prediction effect in the response times is primarily driven by goal-directed behaviours. It could be that the processing for the turn away trials takes a simple category identification approach thus explaining why they still elicit the P3b (Azizian et al., 2006), or that participants simply do not focus on the turn away trials and so they do not create predictions for these trials. However, this is unlikely as instead the P3b effect was larger for the turning away trials than the act towards trials.

As previously suggested (see Chapter One), predictive processing may be impaired in schizophrenia and ASD (Sinha et al., 2014; Teufel, Kingdon, Ingram, Wolpert, & Fletcher, 2010). Indeed, both P3b (Bestelmeyer, 2012; Ford & Mathalon, 2012) and the ACC (Carter et al., 2001; Van Veen & Carter, 2002), tend to be less active in those with

Schizophrenia, demonstrating impairments in conflict monitoring. There also tend to be more backwards connections, and increased neuronal sensitivity, compared to controls suggestive of differential top-down processing in terms of less adjustment to unpredicted stimuli (Fogelson, Litvak, Peled, Fernandez-del-Olmo, & Friston, 2014). Further research highlights how P3b is typically delayed for predictable stimuli in those with schizophrenia in comparison to control participants (Fogelson et al., 2014). The same reduced P3b activation has also been found for ASD (Townsend et al., 2001). Thus these studies may explain the potential impairments in predictive capabilities (Teufel, Fletcher, et al., 2010). This may be due to either impairments in ability to make predictions or, more likely given the extreme desire for routine within individuals with ASD, that there is reduced or impaired feedback to update such predictions when they mismatch reality.

Interestingly, whilst own performance monitoring in individuals with Schizophrenia is impaired as seen by reduced ERN activation, monitoring of others actions appears to be relatively intact as seen by intact oERN activation (De la Asuncion, Docx, Morrens, Sabbe, & De Bruijn, 2015). However, further research is needed to support this finding. Whilst there is limited research investigating ERN within individuals with ASD, the findings indicate lower ERN amplitudes in ASD. A recent review (Hüpen, Groen, Gaastra, Tucha, & Tucha, 2016) highlights a lack of research on oERN in ASD, and only two studies into oFRN (which find conflicting results), so this is clearly a key area for future research.

Whilst the current analyses focused on ERPs, further evidence of internal person-models could also be explored by analysing the oscillatory signatures of action observation such as the mu-rhythm. Mu rhythm is found within the alpha frequency range (8-13Hz) usually in central electrode sites, and is typically suppressed during movement onset (Pfurtscheller & Lopes da Silva, 1999), but also during observations of others' actions (e.g., in adults, Muthukumaraswamy & Johnson, 2004; Oberman et al, 2007, in infants, Marshall & Meltzoff, 2011). Recent research further suggests that mirror neurons may mediate mu rhythm suppression during such observations (Braadbaart, Williams & Waiter, 2013), and even when actions were only predicted to occur (Southgate, Johnson, El Karoui & Csibra, 2010). Thus, in the current study, if participants, indeed, predict the actions of others with their own motor system more evidence of mu suppression would be hypothesised during typical than atypical actions, and more so during the goal-directed act towards rather than turning away trials. Future studies/analyses will explore this possibility.

Experiment 2b – transference between concrete and abstract action knowledge

Experiment 2a provided further evidence towards a predictive internal model account of action observation, and against a mere motor/stimulus learning account for the prediction effects. Experiment 2b was designed to further support this conclusion using a behavioural paradigm to test whether person-knowledge can be generalised across modalities. As such, it would provide further evidence supporting the proposal in Chapter Two that the prediction effects emerge from internal models of the behaviour tendencies of others, and against the counter-argument that they merely reflect stimulus-response or perceptual learning. If participants only engaged in this simple stimulus-response mapping or perceptual learning, then the action intentions they received verbally should not influence their visual action identification responses as they would simply have learned which button to press for each stimulus. This experiment was designed as a more direct test of whether the results reflect prediction of action. If the effects reflect higher-level prediction of action, then they might also be elicited if learning is not based on the stimuli itself, but on other stimuli, which should predict action in a similar way.

In two thirds of the trials participants saw an equal distribution of the actors performing each action in each situation, such that neither actor showed a preference for one particular object or action. Participants identified the action as an interaction or withdrawal in the same way as in the previous experiments. In the other third of the trials, however, the participants saw the neutral photograph only (of the actor stood or sat by the object) and heard the actor utter a verbal expression of intent ("Yeah, I'll have a go", "Nah, I'll leave it"). These verbal expressions were, again, varied such that one actor would always say that they would have a go with one object and would leave the other object (counterbalanced across conditions and participants). Thus, these expressions of intent could provide information to participants of whether the actors intended to act upon or turn away from an object, which could then influence the action identification task (despite these action observation trials actually showing all actions equivocally for each actor with each object). If this knowledge of action intention is transferred to the action identification task, it should be reflected in terms of faster response times and fewer errors when observed actions are congruent to the verbal statements of intent (i.e., when participants observe an action towards an object, if carried out by the actor that previously said they wanted to have a go with the object rather than leave it). Such a finding of transfer from verbal learning to action identification would indicate that the prediction effects of the previous experiments can originate from high-level action knowledge about what the actors might do, instead of just abstract learning of stimulus or response sequences.

Method

Participants

79 participants (70 females, mean age = 20.35 years, *SD* = 4.24; 71 right handed) took part in the study in exchange for course credit. Sample sizes were determined with G-Power (Erdfelder et al., 2007) on the basic paradigm (Experiment 1b), which indicated that a sample size of at least 76 was required to reliably detect an interaction effect of Observed Action and Expected Action based on the assumption that the effect size would be roughly half the size (*dz* = .313) with .80 power to detect an effect size compatible with the previous experiments. Three participants were excluded for making more than 10% errors, and an additional three participants were removed for mentioning the manipulations in the funnel debrief.

Materials and apparatus

The exit questionnaires were identical to previous experiments. The course of the trials was identical to Experiment 1b for two thirds of the trials (112 trials), but all stimuli were presented at equal rates (e.g., John kicked the ball as often as he turned away from it). Again, participants simply had to indicate, as quickly and accurately as possible, whether the actor interacted or turned away from the object, using a button press.

However, in the remaining third of trials (96 trials) participants saw only the neutral photograph (of the actor stood or sat with the object), and heard a verbal statement of intent ("Yeah, I'll have a go", "Nah, I'll leave it"), 500 ms after picture onset, roughly coinciding with the action execution in the other trials. Participants were instructed to simply listen to these statements without making a response.

Trial order was pseudorandomised such that within every 24 trials there were 16 'normal' trials and 8 'verbal' trials presented in random order to more equally disperse the different trial types across the experiment. There were 336 trials altogether.

Procedure

Participants first completed the main computer-based task. They then completed the two exit questionnaires before being fully debriefed.

Results

Funnel debrief

The average overall ease of the task was perceived to be 7.23 (out of 10). The data suggested that the actors and the actions/objects were equally salient with neither being easier to identify conclusively (see Table 3.2).

Table 3.2:

Data showing which actor and which action participants rated as easier to identify for Experiment 2b

Character	**Easiest to identify**	**Action**	**Easiest to identify**
Claire	17	**Ball/kick**	23
John	13	**Computer/type**	15
Neither Claire nor John	49	**Interacting with an object**	14
		Turning away from an object	11
		None	16

Sixty-eight participants (86.08%) did not notice anything unusual in the stimuli, fifty-three participants (67.09%) said they did not notice a pattern, and the rest mentioned similar proposed patterns as in previous experiments. One participant (1.27%)

mentioned that they thought they saw the male kick the ball more and the female use the computer more. One participant (1.27%) stated that the female always said she would leave the ball and take the computer, with the opposite behaviour for the male. Finally, one participant (1.27%) said that the actors would do the opposite of what they would say. As mentioned above, these three participants (3.81%) were removed from the analyses for potential explicit awareness.

7.39% of trials were excluded in total (4.45% for error trials, 2.52% for scores greater than 3 SD from the mean, and 0.42% for Presentation uncertainties). For the response time data, erroneous responses were also excluded. The remaining data were analysed with a repeated measures ANOVA with the factors Observed Action (act towards, turn away) and Expected Action ("Yeah, I'll have a go", "Nah, I'll leave it"), separately for RTs and Error rates.

Response times

The analysis revealed no main effect of Observed Action, $F[1,72] = 2.625$, $p = .110$, $\eta\rho^2 = .035$, and no main effect of Expected Action, $F[1,72] = .219$, $p = .641$, $\eta\rho^2 = .003$. The analysis also failed to reveal the hypothesised interaction between these factors, $F[1,72] = 2.476$, $p = .120$, $\eta\rho^2 = .033$.

Error rates.

The same ANOVA was conducted on the error rates, and revealed a main effect of Observed Action, $F[1,72] = 7.444$, $p = .008$, $\eta\rho^2 = .094$, with a higher proportion of errors for the acting towards ($M = .05$, $SE = .004$) than turning away trials ($M = .04$, $SE = .003$). Whilst there was no main effect of Expected Action, $F[1,72] = .500$, $p = .482$,

$\eta\rho^2 = .007$, there was a borderline statistically significant interaction between these factors, $F[1,72] = 3.793$, $p = .055$, $\eta\rho^2 = .050$. Further analysis (see Figure 3.8) revealed a higher proportion of errors when actors acted upon an object that they had stated they would not act with, compared to when they had stated they would act on it, $t[72] = 1.831$, $p = .071$, $d = .25$. The same pattern was seen numerically for the observation of a turn away action, $t[72] = 1.111$, $p = .270$, $d = .33$.

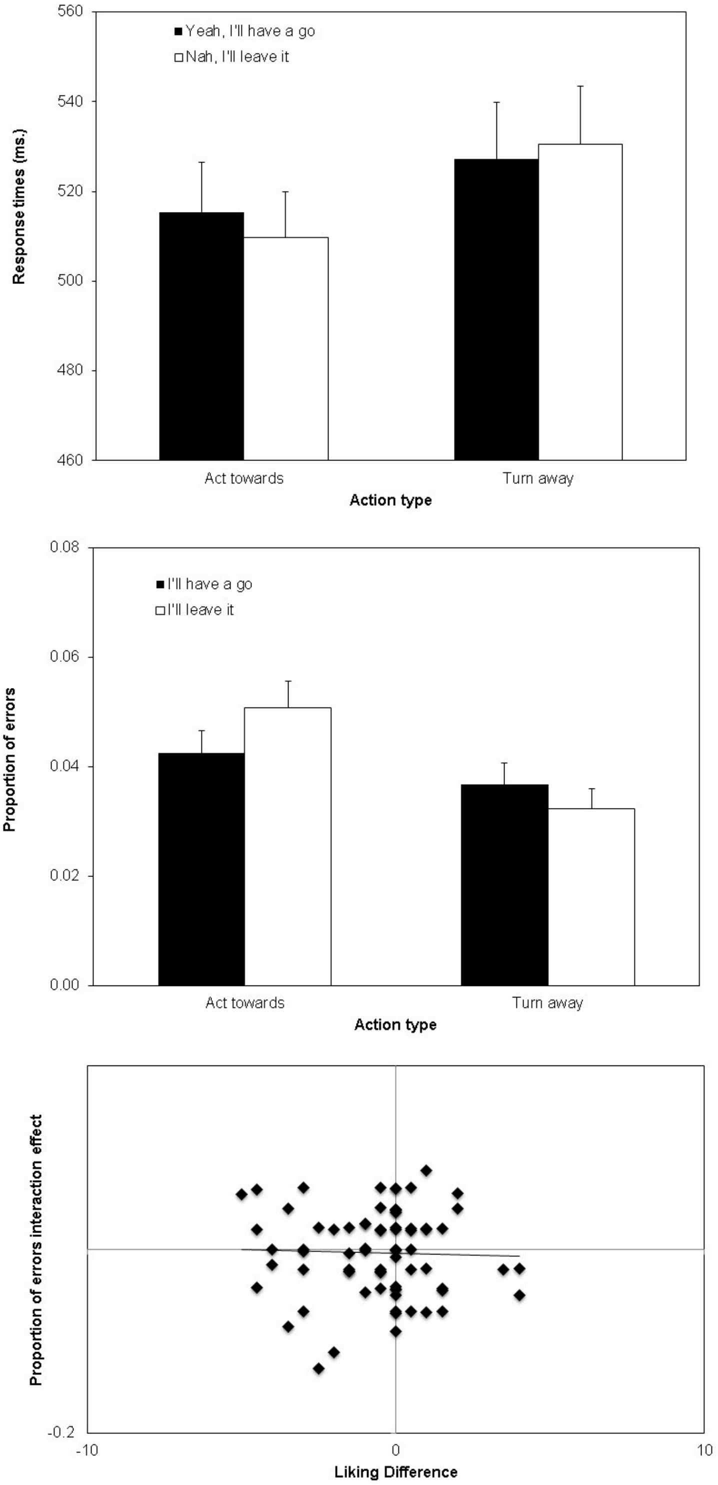

Figure 3.8. Response times, proportion of errors and correlations for Experiment 2b
Average response times (*top panel*) and average proportion of errors (*middle panel*). The left bars show responses for the verbal statement “Yeah, I’ll have a go”, and the right bar shows responses for the statement “Nah, I’ll leave it”. The black bars reflect actions towards objects, and the white bars show the turning away actions. Error bars show the standard error of the mean. The bottom panel shows the correlation between prediction effects for the proportion of errors and the corresponding differences in perceived object liking.

Action identification trials immediately following a verbal trial

In Chapter Two it was proposed that internal models are created relatively implicitly and then tested explicitly in the form of behavioural wagers (Marcus et al., 2006; see also Duran & Dale, 2009). We therefore explored the data for the first two 'normal' trials following a verbal trial using one sample t tests, with the hypothesis that the transfer of verbal to action information more strongly affects the first trial after a trial in which the verbal information was heard.

This analysis revealed that participants made more errors in the trial immediately following a verbal trial if the observed action mismatched the verbal intention than when it matched the verbal intention (e.g., when John said he would have a go with the ball but was then seen turning away from the ball, compared to when he said he would have a go with the ball and was then seen acting towards the ball), *t*[72] = 2.225, *p* = .029. However, there were no differences in proportion of errors based on expectation from the verbal intention in the second subsequent 'normal' trial, *t*[72] = .072, *p* = .943, suggesting that participants rapidly readjusted their hypotheses based on what was actually observed.

Liking

Objects that actors said they would have a go with were rated as more liked by this actor (*M* = 1.26, *SD* = 1.13) than objects they said they would leave (*M* = .65, *SD* = 1.40), *t*[72] = 2.707, *p* = .008, *d* =.48. Whilst in previous experiments correlation and regression analyses were performed on this information in relation to the response time effect, this time the same analyses was performed on the error data (specifically on the interaction effect) and the liking effect. There was no correlation between the interaction in the error data and the liking effect, *r* = -.033, *n* = 73, *p* = .781, and the regression analysis revealed that the intercept was not significantly different from zero (*t* = .753, *p* = .454). This suggests that the effect was only seen in those participants with at least some access to explicit knowledge.

Discussion

Experiment 2b tested whether the actors' abstract verbal statements of intent influenced identification of their future actions to provide further evidence that prediction effects reflect evidence of the behavioural knowledge of actors in given situations rather than simple stimulus-response learning. There was, indeed, evidence for a prediction effect based on person-knowledge, which, contrary to previous experiments, was predominantly seen in the error data. Fewer errors were made when the action matched the verbal intention in previous trials (the actor acted on an object they said they would have a go with and turned from an object they said they would leave) compared to when the action mismatched the verbal intention (the actor acted on an object they said they would leave, and turned from an object they said they would have a go with). Interestingly, the prediction effect was, again, primarily driven by actions towards objects, supporting the previous findings for the special status of object-directed actions. Thus, the data again supports the hypothesis of 'intentional relations' for both abstract and concrete behaviours that are goal-directed (Barresi & Moore, 1996).

One reason the effect may predominantly be seen in the error rates may be because the task is more akin to the 'explicit' experiments in the series (see Chapter Two, Experiments 1c, 1d and 1e). Here, participants may have heard the verbal intention ("Yeah, I'll have a go") and explicitly tested it against the action in the subsequent trial. Indeed, we found more errors for unexpected actions specifically in the first trial after a verbal intention was given. This interpretation would be in line with the Chapter Two proposal that internal models are created relatively implicitly and then tested in the form of explicit behavioural wagers (Marcus et al., 2006; see also Duran & Dale, 2009), and used to update the models. Indeed, anecdotally, in the exit questionnaire (as noted previously), several participants thought that the verbal intentions were contradictory to what was actually seen suggesting that they were testing these verbal intentions against action observations.

Whereas the error data demonstrated a clear positive compatibility effect, no effects were seen in the response time data.

As in Chapter Two, intention (though in this case based on verbal information from the actors) also transferred to post hoc liking ratings; participants rated the actors as liking the objects that actors said they would ‘have a go with’ compared to those they said they would leave, despite no evidence of explicit awareness of this manipulation in the funnel debrief. However, in the current experiment, there was no evidence of a dissociation between implicit and explicit knowledge.

The data therefore provide further evidence against a simple stimulus response learning account. Such an account would predict that there would be faster response times and fewer errors for more frequent pairings, independent of what the actors said they intended to do with the object. However, recall that, in the current experiment, all actions were seen equally often (John kicked the ball as often as he turned away from it). As such, stimulus learning accounts would not predict any differences in response times or error rates across stimuli. Yet, the evidence suggests that participants did use the verbal statements of intent as there were more errors when actors behaved differently than they said they would. This suggests that participants were integrating this higher-level knowledge with their observations of the actors acting with the objects in person-models.

General discussion

The current chapter aimed to provide evidence that person-knowledge really was leading to prediction effects based on the typical actions of two actors in two situations, rather than simply reflecting mere stimulus and/or response learning. Experiment 2a found evidence for components typically found in prediction paradigms and error processing of actions, namely P3b and oERN (Bismark et al., 2013; Carp et al., 2009; Donchin & Coles, 1988; Duncan-Johnson & Donchin, 1982; Koban et al., 2012; Kobza & Bellebaum, 2013; Polich, 2007; van Schie et al., 2004). These effects were modulated by Action Type (act towards, turn away) such that the oERN was only found for the acting towards trials, indicating that participants viewed the unexpected action as an action error on the part of the actor (relative to the person-model), but that the same processing was not applied to the turning away trials. However, independent of whether an act towards or turn away action was observed, greater P3b activity was seen when the action was atypical for the actor in the given situation indicating that during atypical trials the person-models were being updated (Donchin & Coles, 1988; Duncan-Johnson & Donchin, 1982). These findings provide evidence that participants are, indeed, making predictions based on person-models of the actors' behaviour, and against the counter-argument of data simply reflecting mere stimulus-response learning.

Experiment 2b further supported the person-model explanation over a simple stimulus-response bias explanation by demonstrating that verbal statements of intent transferred to action identification, which should not occur with simple motor learning. There were fewer errors (and slower response times) when actions matched the verbal intention of the actor in previous trials (the actor acted on an object they said they would have a go with), compared to when the action mismatched the verbal intention of the actor in previous trials (the actor acted on an object they said they would leave).

Thus, there was evidence of a transfer between verbal intentions and action observation. One caveat is that this transfer was explicitly mediated such that participants were actively assessing whether what the actor said was true in the subsequent action observation trial. The first subsequent ‘normal’ trial after a verbal intention produced more errors when the action displayed mismatched rather than matched that intention. Moreover, anecdotal reports of several participants in the exit questionnaires appeared to reflect a contrast effect between verbal intention and subsequent action, where they perceived the actors to act against their stated intentions. As such, Experiment 2b provided further evidence towards the implicit learning tested by explicit wagers explanation posited in Chapter Two (Marcus et al., 2006; see also Duran & Dale, 2009).

Conclusion

Both experiments provide further support towards the person-model explanation that participants (implicitly) learn the behavioural tendencies of others and reactivate this when they are seen again (Barresi & Moore, 1996). If the previous findings were merely due to a stimulus-response bias then there should be no modulation of ERPs, and no influence of verbal statements of intention, during the action identification task. Instead, there was evidence of a modulation of ERPs based on both Action Typicality and Action Type, and verbal statements of intent did influence action identification responses. Crucially, there was also evidence of ERP components typically activated during predictive coding tasks (P3b, oERN).

Chapter Four – the predictive influence of pre-existing person-models on motor biases

Recently, it has been suggested that people identify the actions of others by ‘mapping’ these actions onto their own motor system, to help derive their associated internal states (e.g., Gallese et al., 1996; Rizzolatti & Craighero, 2004; Sparenberg, Springer, & Prinz, 2012; Wilson & Knoblich, 2005). In other words, people understand the action because they simulate how they themselves would perform that action; how it would feel to them, and what internal states it would activate, which is then attributed to their interaction partner.

Research in this motoric understanding of actions has grown exponentially since the discovery of ‘mirror’ neurons, which fire both when performing an action and when observing that same action (e.g., di Pellegrino et al., 1992; Rizzolatti et al., 1996). There is much debate as to their purpose, with some theorising that mirror neurons are a mechanism for mapping observed actions onto our own motor system (e.g., Wilson & Knoblich, 2005) to help us understand our interaction partners and make predictions about how they will behave (e.g., Gallese et al., 1996; Rizzolatti & Craighero, 2004). For example, there is evidence that action initiation is faster in humans when a co-actor shares the same (rather than a different) action intention, which suggests the use of the same goal representation for self and other (Ondobaka, de Lange, Newman-Norlund, Wiemers, & Bekkering, 2012).

Such accounts typically assume that mirror neurons are primarily stimulus-driven: mirror neurons represent the actions we observe, matching it with prior knowledge in a primarily bottom-up fashion (e.g., Gallese et al., 1996; Rizzolatti & Craighero, 2004). However, more recently there has been a move away from such exclusively bottom-up accounts towards a view that perception in general – social and otherwise – is also influenced by prior knowledge and predictions (Bubic et al., 2010; A. Clark, 2013; den Ouden et al., 2012; Friston & Kiebel, 2009). These models assume that the brain is constantly making predictions for what will happen next, and testing them against the perceptual input. Evidence suggests that such a bias in perception occurs very early in processing, at least for non-social perception (den Ouden et al., 2012; Gamond et al., 2011; Senior, Ward, & David, 2002), but similar evidence is emerging for social stimuli in person perception (Macrae & Bodenhausen, 2001), gaze perception (see Teufel, Fletcher, et al., 2010), and action perception (Hudson, Nicholson, Simpson, Ellis & Bach, 2015) as well.

In such models, contrary to purely bottom-up theories, goals rather than action kinematics are being simulated. Activation of the associated actions occurs in a second step when observers predict ("emulate") the action they would do to achieve the goal (e.g., Hickok, 2009; Kilner et al., 2007). Such an account proposes that perception is biased by predictions at multiple levels of the behaviour-goal hierarchy (see Bubic et al., 2010; A. Clark, 2013; den Ouden et al., 2012; Friston & Kiebel, 2009), for example, on both lower levels (John will kick the ball) and higher levels (John wants to score a goal). Mismatches between what is expected and what is actually observed lead to prediction errors, which are then fed back up the hierarchy. For example, knowing John likes football would lead to the prediction that he would kick a ball in the park, and surprise (i.e., a prediction error) if he is, instead, seen in the park having a picnic whilst his friends are playing football.

Prior chapters provide evidence that such predictions elicit biases in action identification, and we have also recently shown how these predictions also elicit attentional biases, namely that observers direct attention not only to where someone is looking, but also to where they expect them to look (Joyce et al., 2015). However, recent predictive coding models would further hypothesise that predictions also elicit motor biases, as it is assumed that expected actions of another person are derived via the observers' own motor system (Kilner & Frith, C.D. 2007; Kilner et al., 2007). Indeed, there is evidence of forward models for motor commands showing people's ability to predict the consequences of their own motor actions (for a review, largely within saccadic eye movements, see Shadmehr, M.A. Smith & Krakauer, 2010; for a model of adaptation and anticipation within sensorimotor synchronisation see van der Steen & Keller, 2013). There is also evidence for anticipatory motor activations during action observation (Avenanti, Annella, Candidi, Urgesi, & Aglioti, 2013) suggesting that we predictively code others' actions (Urgesi et al., 2010). Similarly, infants who were not yet proficient walkers could predict crawling more accurately than walking, whereas infants who were proficient in both walking and crawling showed no difference in predictive accuracy (Stapel, Hunnius, Meyer, & Bekkering, 2016). These studies highlight the use of the motor system during predictions of action observations.

The experiments in this chapter build on these effects to test whether person-models of others are also embodied, in the sense that predictions can be attributed from observers' involuntary motor responses when seeing these individuals. The experiments build upon prior work by Bach and Tipper (2006; see also Tipper & Bach, 2011) who asked participants to identify famous football and tennis players with either a hand or foot response. They investigated whether the typical body part – the one most frequently used in the sport – was activated even if the athletes were not currently seen executing their typical action (kicking a ball, using a racket), implying motor activation that reflects the action anticipated from the actors rather than what is currently observed.

While Bach and Tipper's (2006) results took the form of contrast rather than facilitation effects, impairing the body part that was used in the athletes' sport (e.g., slower responses for hand than foot responses for tennis players, and vice versa for football players), they nevertheless suggest that participants were using their own motor systems to represent knowledge about the athletes because the athletes' main effector influenced the motor response required, even though action knowledge was not required for the task. This may be a result of the arm being 'reserved' for the tennis players and the foot for football players, and so the other effector is easier to access leading to the contrast effects.

Moreover, the results showed that motor activation was person-specific, that is, different body parts were affected for different athletes, depending on the body part primarily used in their sport. This supports the notion of person-models for action observation described in Chapter Two. In this case Wayne Rooney is associated with kicking footballs whereas Andy Murray is associated with playing tennis. In this view, the negative compatibility effects might, therefore, reflect a prediction error: that an expected action (i.e., a kick for Wayne Rooney) was not observed, leading to an inhibition of the associated motor response. Indeed a further experiment using the same paradigm (Tipper & Bach, 2011) showed that the usual positive compatibility effects are, indeed, observed when the same athletes were shown carrying out their sport (hitting a tennis ball or kicking a football).

The current experiments will test whether such effects emerge from the activation of internal person-models for action prediction. According to the results of the previous experiments, internal person-models are both person- and situation-specific, specifying how an individual acts in different situations. In other words, participants should not predict that Wayne Rooney should kick in general; instead, a kick should only be predicted when he is seen on the football pitch. Similarly, a famous tennis player should only be predicted to use the racket when on the tennis court, but not at a wedding. This situation-specificity and resulting action activation leads to the prediction that both the negative compatibility effects (when athletes are not carrying out the expected actions) and the positive compatibility effects (when they are acting) should only be observed (or should at least be stronger) when the athletes are observed in their sporty contexts (i.e., on the football pitch or tennis court, wearing the associated attire).

To test these hypotheses, the current two experiments presented four famous athletes either acting, or not acting, in and out of their typical contexts, and participants had to identify these athletes using either a keyboard or a foot pedal. This establishes whether the athletes' typical actions are embodied within the observer such that footballers are identified more slowly when using a foot compared to a hand response when seen not acting, and vice versa when acting (and that tennis players show the opposite pattern). For the first time, both the context and action factors were fully counterbalanced such that athletes could either be seen (1) carrying out their sporty hand and foot actions or standing passively, and (2) in either their sporty contexts (tennis court, football pitch) or outside it (i.e., on the beach).

The current paradigm extends the previously proposed person-model in at least three ways. First, it tests whether the predictions derived from these models are embodied and lead to measurable changes in motor output. This would help address one of the key counter-arguments against the proposed person-model theory of the first paradigm (Chapter Two), namely that the effects could merely be due to familiarity with the most frequently seen stimuli (e.g., one person kicking but not turning away from a football) or mere stimulus-response associations. Whilst Chapter Three provides preliminary evidence against this interpretation, the current paradigm would further counter this argument, by revealing that person prediction happens on an embodied level, thereby clearly linking it to reflecting action information rather than other, more abstract, stimulus attributes.

Second, it tests whether such models extend to knowledge held about individuals prior to the experiment. In Chapter Two, prior knowledge was created by setting up situations in which participants can learn how actors behave in different situations, and these stimuli were, by necessity, limited and constrained. In contrast, this chapter explores pre-existing knowledge that participants had prior to this experiment, (often for many years) and which was acquired in everyday, non-experimental settings.

Third, it allows us to separate the hypothesised person-models from different potential models that can explain the positive and negative athlete compatibility effects in prior research. One alternative possibility is that person and situation do not interact to specify the most likely forthcoming actions (as proposed in previous chapters), but that they predict action independently. If this is the case, then there should be stronger motor activation when the athlete is in their typical situation next to the associated objects (football pitch, tennis court), and there should be stronger activation whenever they perform their typical action (kicking the ball, hitting a ball with their tennis racket).

A second alternative possibility is that person-models are accessed in stages. For example, how a person looks and the situations they are typically seen in might be the most relied upon factors that guide imitation of the athletes, with the specifics of this person-knowledge (motor information, contextual cues, etc.) only being activated when there is uncertainty. For example, when Wayne Rooney is seen in his typical context performing his typical action, no further information (i.e., person-knowledge) is required. However, if Wayne Rooney is seen in an atypical context it may elicit a prediction error, and so more detailed person-knowledge held about him may be activated to reduce the uncertainty. As such, motor information (i.e., the knowledge that

Wayne Rooney typically kicks a ball) should not be activated when he is seen in context, instead it should be predominantly observed when he is seen out of context. Numerically, at least Tipper and Bach (2011) provide support for this outcome, with negative compatibility effects being numerically larger in the out-of-context condition.

Experiment 3a – Action prediction based on pre-existing person-knowledge

The previous experiments investigated person-knowledge gained during the course of an experiment. Experiment 3a investigated the influence of action knowledge about individuals gained prior to the experiment, and tests whether this affects motoric ("mirror") representations of others' actions. Finding such motoric effects of anticipated actions would solve the problem in the previous chapters of whether the prediction effects truly reflect anticipation of the forthcoming action, rather than other stimulus or response aspects that could be encoded in a non-social format. In contrast, finding that the participants' motor system would, in some way, represent the not observed (but predicted) action of somebody else would provide clear evidence for such a social prediction of others' actions.

Participants were presented with photographs of famous football and tennis players – Wayne Rooney, Cristiano Ronaldo, Andy Murray and Roger Federer – either acting, or not acting, in a neutral context or in their usual sports context, in a fully counterbalanced factorial design. Participants had to identify these actors with hand and foot responses, such that one tennis player (e.g., Andy Murray) and one footballer (e.g., Wayne Rooney) would have to be identified with a foot response, and the others with a hand response (e.g., Roger Federer and Cristiano Ronaldo). This tests whether the athletes' actions are embodied within the observer such that the congruency of the participants' identification response with the body part typically used in the athletes' actions affects response times.

Prior research has suggested that these motoric activations do, indeed, have some predictive components (Bach & Tipper, 2006; Tipper & Bach, 2011). When the athletes were seen acting and carrying out their typical behaviours (tennis players hitting a ball and footballers kicking), the well-known positive compatibility ("mirror") effects were found (e.g., Bach et al., 2007; Brass et al., 2000), such that athletes were identified more quickly with the body part primarily used in their sport. Crucially, however, congruency of body parts used for identifying the athletes affected response times even if the athletes were not seen acting, and so their actions could only be predicted. Importantly, these took the form of negative compatibility effects, that is, a tennis player took longer to be identified with a hand than a foot response and vice versa for football players. This could be taken as evidence for predictive processing, where the expected action is represented as "missing" and, therefore, elicits negative compatibility effects.

The goal of Experiment 3a is, firstly, to replicate these negative compatibility effects. Second, this paradigm tested whether these effects reflect underlying person-models that predict others' behaviour in different circumstances, such that the negative compatibility effect codes the absence of the clearly expected action from this athlete. Recall that in the previous experiments in this thesis, anticipation of action always occurred not only in a person but also a situation-specific manner. If our embodied knowledge of the athletes' sport emerges from similar underlying person-models, then these effects should also be modulated by context. It would then be hypothesised that the negative compatibility effects should be stronger when the athlete is in their typical situation (e.g., on a football pitch), where they would be expected to perform these actions, compared to an atypical situation (e.g., at a wedding), where such an action expectation is reduced.

Method

Participants

43 participants (34 females, mean age = 20.86 years, SD= 4.49; 38 right handed) took part in the study in exchange for course credit. Samples sizes were based on the two previous experiments (Bach & Tipper, 2006; Tipper & Bach, 2011). Four participants had technical difficulties with the foot pedal and were excluded from the analysis.

Materials and apparatus

The apparatus was identical to the previous experiments. Photographs of four athletes were presented; two footballers (Wayne Rooney, Cristiano Ronaldo) and two tennis players (Andy Murray, Roger Federer). Each athlete was shown in two photographs for each of the four conditions (acting in context, not acting in context, acting out of context, not acting out of context). Therefore, there were 32 photographs in total. Actions out of context could be in any situation that was not a tennis court or football field for example at an awards ceremony, at the beach, etc. (see Figures 4.1 & 4.2).

Figure 4.1. has been removed due to Copyright restrictions.

Figure 4.1. An example of the typical action conditions for Experiment 3a.
Andy Murray is playing tennis (*left)* in context on a tennis court and (*right*) out of context on a beach

Figure 4.2. has been removed due to Copyright restrictions.

Figure 4.2. An example of the non-action conditions for Experiment 3a.
Andy Murray is seen not performing his typical action of playing tennis (*left)* in context on a tennis court and (*right*) out of context on a beach

A questionnaire asked how often participants had seen each athlete playing tennis/football, how skilled they thought the athlete was compared to other professionals within their sport, how talented they thought the athlete would be at the other sport (e.g., for Andy Murray, participants were asked how talented they thought he would be at football), and finally how much participants liked each athlete. For each question, participants responded on an 8-point Likert scale from -4 to +4 with no zero point.

The social intelligence scale (Silvera et al., 2001) was administered to test correlations between self-report measures of social intelligence and response time effects. However, there were no significant correlations so this will not be discussed further.

Procedure

Participants were only invited to take part in the study if they could recognise each of the four athletes to ensure the reactivation of this prior knowledge during the experiment.

Participants were instructed to identify the athletes as quickly and as accurately as possible using either a keyboard or a foot pedal. One footballer and one tennis player had to be identified using the foot pedal, and the second footballer and tennis player had to be identified using the keyboard (counterbalanced across participants).

Each trial consisted of a fixation point in the centre of the screen for between 800 and 1000 ms (randomly chosen) followed by the photograph of one of the athletes in one of the conditions. This image stayed on screen for a maximum of 2000 ms if no response was given. If participants responded correctly they were shown a blank screen for 300 ms, if not they were given a reminder of which pedal to press for each athlete for 3000 ms. There were 384 trials in total – 12 blocks of the 32 photographs presented in random order using E-Prime 2.0 (Psychology Software Tools, Pittsburgh, PA). There was an opportunity for a short break halfway through if the participants wanted one.

Finally, participants filled out the exit questionnaire and the social intelligence scale, and were debriefed and thanked for their participation.

Trial exclusions

As in previous chapters, trials were excluded if they had RTs greater than the trial duration, and if they had RTs greater than three standard deviations from the participants' condition mean. For the analysis of RTs, error trials were additionally excluded. However, due to the increased task difficulty compared with the previous paradigm, participants were excluded if they made more than 20% errors, though none did in either experiment.

Results

6.44% of trials were excluded in total (4.79% for error trials, and 1.65% for response times greater than 3 SD from the mean).

Response times

For the remaining data, a repeated measures ANOVA was performed with the factors Context (in context, out of context), Action (action, non-action) and Effector Congruency (congruent with athlete's typical effector, incongruent with athlete's typical effector), and Counterbalance (Rooney/Murray hand and Ronaldo/Federer foot identification, Rooney/Murray foot and Ronaldo/Federer hand identification, Ronaldo/Murray hand and Rooney/Federer foot identification, Ronaldo/Murray foot Rooney/Federer hand identification) as a between subjects factor of no interest.

There was no overall main effect of Effector Congruency, $F[1,35] = 1.111$, $p = .299$, $\eta\rho^2 = .031$. However, there was a main effect of Context, $F[1,35] = 80.740$, $p < .001$, $\eta\rho^2 = .698$, with faster response times for identification of athletes out of context ($M = 731.01$, $SE = 10.18$) than in context ($M = 763.69$, $SE = 11.62$). There was also a main effect of Action, $F[1,35] = 9.278$, $p = .004$, $\eta\rho^2 = .210$, with faster response times when athletes performed their typical action ($M = 743.30$, $SE = 10.57$) than when they did not ($M = 751.41$, $SE = 11.12$). The predicted three-way interaction of Context, Action and Effector Congruency was not significant, $F[1,35] = .048$, $p = .827$, $\eta\rho^2 = .001$, but, as in the original studies (Bach & Tipper, 2006; Tipper & Bach, 2011), there was a significant interaction between Action and Effector Congruency, $F[1,35] = 5.580$, $p = .024$, $\eta\rho^2 = .138$ (all other effects, $F[35] \leq .750$, $p \geq .392$), showing negative congruency effects when athletes were seen not acting. Planned comparisons on Action and Non-Action trials separately with Counterbalance as a factor of no interest revealed no main effects or interactions for the action trials, largest $F[1,35] \leq 1.251$, smallest $p \geq .306$, but there were slower response times for congruent ($M = 759.71$, $SE = 10.96$) than incongruent ($M = 746.80$, $SE = 10.59$) stimuli, $F[1,35] = 5.410$, $p = .026$, $\eta\rho^2 = .134$ for the non-action trials.

As a direct effect of context on the congruency effects was hypothesised, planned comparisons were then performed on the in context and out of context trials separately with Counterbalance as a factor of no interest. For the in context trials, this revealed no main effects or interactions, largest $F[1, 35] \leq 2.162$, smallest $p \geq .150$. However, the same analyses for the out of context trials revealed that there was a near significant main effect of Effector Congruency, $F[1,35] = 3.359$, $p = .075$, $\eta\rho^2 = .088$, with faster responses for incongruent ($M = 726.40$, $SE = 10.13$) than congruent ($M = 735.63$, $SE = 10.82$) responses. The out of context trials also showed an interaction of Action and Effector Congruency that was borderline significant, $F[1,35] = 3.8341$, $p = .058$, $\eta\rho^2 = .099$. Further planned comparisons revealed that response times were faster when non-actions were identified with the incongruent than congruent effector, $F[1,35]= 8.483$, $p = .006$, $\eta\rho^2 = .195$. The same effect was not observed for the typical actions, $F[1,35]= .110$, $p = .742$, $\eta\rho^2 = .003$.

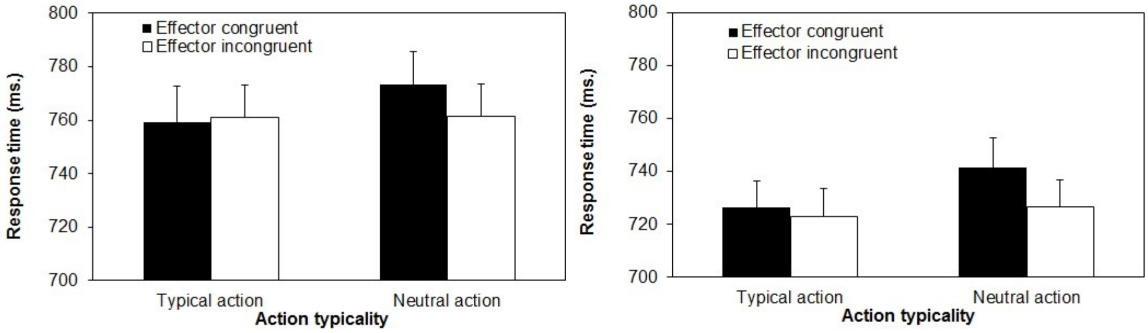

Figure 4.3. Average response times for Experiment 3a.
The left graph reflects average response times in context, and the right graph reflects average response times out of context. The left bars reflect typical actions, and the right bars represent atypical actions. The black bars show identification with a congruent effector, and the white bars show identification with an incongruent effector. Error bars show the standard error of the mean.

Errors

A parallel ANOVA was carried out on the error rates. There were no main effects of Action, *F*[1, 35]= 1.105, *p* = .300, $\eta\rho^2$= .031 nor Effector Congruency, *F*[1, 35]= 1.571, *p* = .218, $\eta\rho^2$= .043, but there was a main effect of Context, *F*[1, 35]= 14.323, *p* = .001, $\eta\rho^2$= .290. Participants made a higher proportion of errors when identifying athletes in context (*M* = .054, *SE* = .005) than out of context (*M* = .040, *SE* = .004). The critical three-way interaction was not significant, *F*[1, 35]= .017, *p* = .898, $\eta\rho^2$= .000, nor were any of the other interactions, largest *F*[1, 35] ≤ 1.347, smallest *p* ≥ .254 (see Table 4.1). Planned comparisons revealed no further main effects or interactions for the in context trials, largest *F*[1, 35] ≤ 2.476, smallest *p* ≥. 125, nor the out of context trials, largest *F*[1, 35] ≤ .503, smallest *p* ≥ .683.

Table 4.1

The mean proportion of errors for in context and out of context trials with standard deviations in brackets for Experiment 3a

	Typical action		**Neutral action**	
	Effector congruent	**Effector incongruent**	**Effector congruent**	**Effector incongruent**
In context	.053 (.037)	.060 (.035)	.046 (.040)	.057 (.046)
Out of context	.040 (.034)	.040 (.033)	.040 (.037)	.041 (.031)

Liking & Skill ratings

To investigate the influence of prior knowledge and attitudes towards the athletes on the above effects, separate regression analyses were conducted for the RT Action by Effector Congruency interaction effect, and the equivalent error interaction effect (see Table 4.2). Even though there was no significant facilitation effect, motor priming effects for typical actions in the response times were stronger for participants who rated the athletes as more skilled in their own sport and, to a lesser extent (p = .075), those who were more familiar with the athletes (replicating Tipper & Bach, 2011), suggesting that the predicted facilitated Congruency effect for Action stimuli was present in those participants that knew the athletes better. However, as in the previous studies, there were no relationships involving the skill participants perceived the athletes to have in the other sport (e.g., the skill of a football player at playing tennis) nor liking for the athletes. There were no significant relationships for the error data.

Table 4.2.

Regression analysis for Experiment 3a; standardised beta coefficients describing the relationships between motoric priming and participant prior knowledge and liking of the athletes for RTs (based on the interaction of Typical Action by Effector Congruency) and error data.

Predictor	**Motor Priming effect**	
	RTs	**Errors**
Familiarity	-.331	-.008
Skill: Athlete's own sport	-.381*	.102
Skill: Other sport	0.89	.039
Liking	.180	.202

* p < .05

Discussion

Experiment 3a tested whether seeing a famous athlete primes the main effector used in their sport such that when a famous tennis player like Andy Murray is seen, the participants' own arm is activated, even when Andy is not currently seen acting with his arm. Crucially, a fully factorial design manipulated whether presenting the athletes in or out of their typical contexts modulates the size of the resulting facilitation or inhibition effects. It was hypothesised that, as in previous chapters, participants would re-activate person-models of the athletes, which would then activate the typical actions they carry out in different situations. Therefore, both negative and positive compatibility effects should be stronger when the athlete is observed in their typical situation (e.g., on a football pitch), where they would be expected to perform these actions, compared to an atypical situation (e.g., at a wedding), where such an action expectation is reduced. However, the results did not support this prediction.

The results replicated previous findings that viewing athletes famous in their sports influenced observer motor systems (Bach & Tipper, 2006; Tipper & Bach, 2011), even if the athletes were not shown performing their typical actions. As before, participants showed negative compatibility effects when the athletes were not performing their sport (i.e., slower to respond when they must identify Andy Murray using a hand response compared to a foot response). As in Tipper and Bach (2011), these effects were eliminated when viewing the athletes performing their typical actions. These findings suggest that merely seeing Andy Murray elicits the expectation that he will use his arm. This priming facilitates responses with the same effector when observers see him performing as expected. In contrast, when he is not performing his expected action, this appears to be coded as an absence - a negative deviation of an action that was expected – and elicits negative compatibility effects.

These results are in line with the notion of person-specific internal models that predict the actions of other people. Participants responded differently depending on whether they see someone who typically uses their arm (or leg) even though this was not task-relevant, based only on their prior history with watching these athletes outside of the experimental context. This would not be hypothesised by simple stimulus-response accounts. Thus, as seen in Chapter Two, *who* is being observed is important and directly affects one's own motor responses. This reliance on prior knowledge is supported by the replication of Tipper and Bach's (2011) finding that knowledge about the athletes influenced the motor priming effects. Those participants who rated the athletes as more skilled in their sport (and, to a lesser extent, those who had more knowledge of the athletes) showed the strongest motor priming effects. This highlights how perception of the athletes being particularly skilled in their sport influenced motor priming towards them. It is striking that for this person-identification task, information about behavioural tendencies (which is not task-relevant) still influenced response times.

However, the current experiment does not support Barresi and Moore's (1996) argument, or previous findings (Chapters Two and Three), that situation is an important factor in intentional relations. It was predicted that, if the effects reflect the activation of internal person-models, the negative compatibility effects should be stronger when the athlete is in their typical situation (e.g., on a football pitch), where they would be expected to perform these actions, compared to an atypical situation (e.g., at a wedding), where such an action expectation is reduced. However, the same pattern of results was seen irrespective of context, whether the athletes were identified in their usual contexts (football field, tennis court) or in other, more neutral situations, suggesting that the main determinant of these effects is the identity of the actor, but not the situation they are in. Whilst the interaction was not significant (and power analyses revealed sample sizes of over 1000 participants would be required to find such an effect), numerically the data suggested the strongest compatibility effects for the out of context stimuli. If replicated, this would provide tentative support for the person-model hypothesis; that a person-knowledge heuristic is activated when the individual is seen, but the details of this are only ‘unpacked’ if there is uncertainty, such as seeing the athlete in unusual situations. The out of context stimuli would lead to the most uncertainty, which would explain the stronger compatibility effects.

These results differ from those reported in Chapter Two, which demonstrated that actor, action and situation are all important factors influencing responding. Therefore, each of these cues may have a different weighting within prediction, with a much lesser weighting for situation. However, here, the task was to identify the actor, making their identity task-relevant. Context, in contrast, varied incidentally, and thus it is perhaps not surprising that it had little effect. Experiment 3b more directly manipulated the salience of the contextual information to test whether these changes affect whether it influences the congruency effects, and assimilated the paradigm more closely with Chapter Two.

Experiment 3b – the influence of pre-existing person-knowledge when highlighting context

The experiments in Chapter Two showed that action prediction occurred in a situation-specific manner during action identification, but Experiment 3a failed to support this hypothesis when measuring embodied activation of action knowledge about famous athletes in a person-identification task. One difference between these experiments is that Chapter Two first showed a neutral image of the actors stood or sat by the objects before presenting a second image of the action. This prior viewing of the context may have provided the crucial cues needed to reactivate the behavioural tendencies of the actors. Thus, in Experiment 3b, situation cues (a tennis court, football pitch, or one of two beach scenes) were provided prior to the critical image of the athletes to provide more time for processing context. It was also hoped that this may reduce some of the ‘noise’ in the previous data to reduce the minimum sample size of participants needed to find the three-way interaction. In light of this it was, again, hypothesized that the negative compatibility effects should be stronger when the athlete is in their typical situation (e.g., on a football pitch), where they would be expected to perform these actions, compared to an atypical situation (e.g., at a wedding), where such an action expectation is reduced.

Method

Participants

56 participants (35 females, mean age = 21.29 years, SD = 5.28; 49 right handed) took part in the study in exchange for course credit. Sample size was determined with G-Power (Erdfelder et al., 2007) based on Experiment 3a, which indicated that a sample

size of at least 50 was required to reliably detect the interaction between Action and Effector Congruency with .80 power.

Materials, apparatus and procedure

The questionnaires were identical to the previous experiments. However, the photographs were altered so that all out of context photographs showed the actors on the beach to reduce possible confounds in the previous stimuli whereby the out of context photographs could be in several situations (e.g., at awards, in the street, or on the beach). An additional photograph of either a beach scene or a tennis/football scene was also now presented prior to the critical photograph. Whilst a tennis or football scene is unambiguously predictive of subsequently viewing a football or tennis player, a beach scene does not predict whether a football or tennis player will be seen. To reduce this potential confound, one specific beach scene was assigned to tennis players and one to football players.

Each trial consisted of a fixation point in the centre of the screen for between 800 and 1000 ms (randomly chosen) followed by the photograph of the context (beach scene one/tennis court for the tennis players or beach scene two/football pitch for the football players) for 500 ms, followed by a photograph of one of the athletes in the related situation. As before, this photograph stayed on screen for a maximum of 2000 ms if no response was given. If participants responded correctly they were presented with a blank screen for 300 ms, if not they were reminded which response to press for each athlete for 3000 ms. There were 384 trials in total – 12 blocks of the 32 photographs presented in random order. Again, there was an opportunity for a short break halfway through if the participants wanted one.

Results

Response times

7.12% of trials were excluded in total (5.29% for error trials, 1.83% for scores greater than 3 SD from the mean).

As before, the remaining data were analysed with a repeated measures ANOVA with the factors Context (in context, out of context), Action (action, non-action) and Effector Congruency (congruent with athlete's typical effector, incongruent with athlete's typical effector) and Counterbalance (Rooney/Murray hand and Ronaldo/Federer foot identification, Rooney/Murray foot and Ronaldo/Federer hand identification, Ronaldo/Murray hand and Rooney/Federer foot identification, Ronaldo/Murray foot Rooney/Federer hand identification) as a between subjects factor of no interest.

The analysis revealed no overall main effect of Effector Congruency, $F[1,52] = .016$, $p = .901$, $\eta\rho^2 < .001$ nor of Action, $F[1,52] = .244$, $p = .624$, $\eta\rho^2 = .005$. However, there was a main effect of Context, $F[1,52] = 14.524$, $p < .001$, $\eta\rho^2 = .218$. Response times were, again, faster out of context ($M = 763.32$, $SE = 10.73$) than in context ($M = 776.24$, $SE = 11.42$). The predicted three-way interaction was not significant, $F[1,52] = 1.579$, $p = .215$, $\eta\rho^2 = .029$. Replicating Experiment 3a, and the previous experiments by Bach and Tipper (2006), there was an interaction between Action and Effector Congruency, $F[1,52] = 6.531$, $p = .014$, $\eta\rho^2 = .112$. There was also an interaction between Action and Context, $F[1,52] = 5.021$, $p = .029$, $\eta\rho^2 = .088$. However, the interaction between Context and Effector Congruency was not significant, $F[1,52] = .082$, $p = .776$, $\eta\rho^2 = .002$.

Planned comparisons were performed to further resolve the two-way interaction between Action and Effector Congruency with Counterbalance as a factor of no interest.

They revealed that response times were faster when typical actions were identified with the congruent than incongruent effector, $F[1,52] = 4.148$, $p = .047$, $\eta\rho^2 = .074$, showing positive compatibility effects. The negative compatibility effect seen in Experiment 3a, and previous research (Bach & Tipper, 2006; Tipper & Bach, 2011), just failed to reach marginal significance, $F[1,52]=2.744$, $p = .104$, $\eta\rho^2 = .050$.

As in Experiment 3a, planned comparisons were conducted for the in context and out of context trials separately with Counterbalance as a factor of no interest. For the in context trials, there was a main effect approaching significance for Action, $F[1,52] = 3.303$, $p = .075$, $\eta\rho^2 = .060$, with faster response times for action ($M = 772.29$, $SE = 11.60$) than non-action stimuli ($M = 780.19$, $SE = 11.65$). However, there were no other main effects or interactions, largest $F[1,52] \leq 1.434$, smallest $p \geq .237$. However, for the out of context trials there were no main effects, largest $F[1,52] \leq 1.558$, smallest $p \geq .218$, but, as in Experiment 3a, there was an interaction between Action and Effector Congruency, $F[1,52] = 6.748$, $p = .012$, $\eta\rho^2 = .115$.

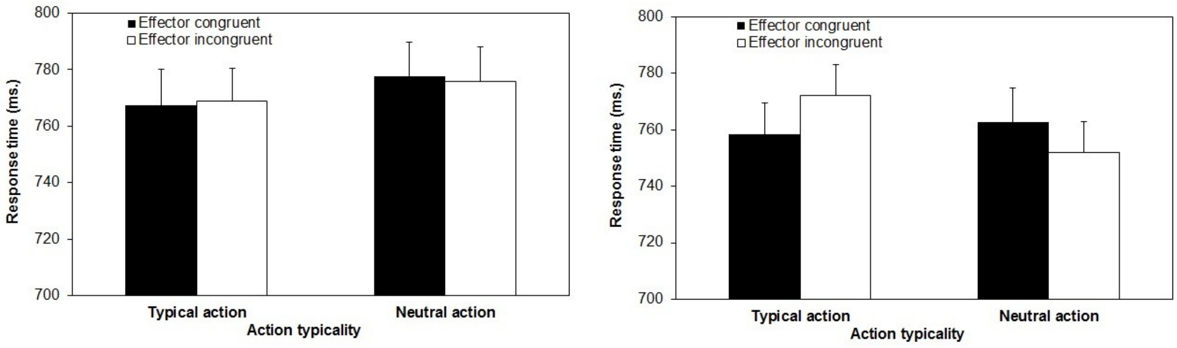

Figure 4.4. Average response times for Experiment 4b
The left graph reflects average response times in context, and the right graph reflects average response times out of context. The left bars reflect typical actions, and the right bars represent atypical actions. The black bars show identification with a congruent effector, and the white bars show identification with an incongruent effector. Error bars show the standard error of the mean.

Errors

The same ANOVA was conducted on the error data and revealed no main effect of Effector Congruency, $F[1,52] =.977$, $p = .328$, $\eta\rho^2 = .018$, but there was a main effect of Context, $F[1,52] =15.767$, $p < .001$, $\eta\rho^2 = .233$, and a near-significant main effect of Action, $F[1,52] =3.029$, $p = .088$, $\eta\rho^2 = .055$. There were a higher proportion of errors in ($M = .04$, $SE = .003$) than out of context ($M = .030$, $SE = .003$), and when the athletes performed their typical action ($M = .04$, $SE = .003$) compared to a neutral action ($M = .03$, $SE = .003$). However, the predicted three-way interaction was, again, not significant, $F[1,52] = 2.189$, $p = .145$, $\eta\rho^2 = .040$. Indeed, the only near-significant interaction was between Context and Action, $F[1,52] = 3.591$, $p = .064$, $\eta\rho^2 = .065$, for all other interactions; largest $F[52] \leq .997$, smallest $p \geq .328$.

As with the RTs, planned comparisons were conducted separately for in and out of context trials with Counterbalance as a factor of no interest. For the in context trials there was only a main effect of Action, $F[1,52] = 5.046$, $p = .029$, $\eta\rho^2 = .088$, all other main effects and interactions were $F[52] \leq .095$, $p \geq .759$. For the out of context trials there was only a near-significant interaction of Action and Effector Congruency, $F[1,52] =3.593$, $p = .064$, $\eta\rho^2 = .065$, all other main effects and interactions were; largest $F[52] \leq 1.977$, smallest $p \geq .166$.

Further planned comparisons were performed to further resolve the two-way interaction of Action and Effector Congruency with Counterbalance as a factor of no interest. Whilst there was no difference in the proportion of errors for congruent than incongruent responses to typical actions out of context, $F[1,52]= .016$, $p = .899$, $\eta\rho^2 < .001$, there was a higher proportion of errors for congruent compared to incongruent responses to non-actions out of context, $F[1,52]=5 .137$, $p = .028$, $\eta\rho^2 = .090$, showing, again, the expected negative compatibility effect in this condition.

Table 4.3

The mean proportion of errors for in context and out of context trials with standard deviations in brackets for Experiment 3b

	Typical action		**Non-action**	
	Effector congruent	**Effector incongruent**	**Effector congruent**	**Effector incongruent**
In context	.046 (.036)	.047 (.032)	.038 (.035)	.038 (.035)
Out of context	.034 (.030)	.034 (.031)	.030 (.028)	.040 (.035)

Liking

To investigate the influence of prior knowledge and attitudes towards the athletes on the above effects, separate regression analyses were conducted for the RT Typical Action by Effector Congruency interaction effect, and the error interaction effect (see Table 4.4). However, there was little effect of prior knowledge of the athletes.

Table 4.4

Regression analysis for Experiment 3b; standardised beta coefficients describing the relationships between motoric priming and participant prior knowledge of liking of the athletes for RTs (based on the Action by Effector Congruency interaction) and error data.

Predictor	**Motor Priming effect**	
	RTs	**Errors**
Familiarity	.187	.002
Skill: Athlete's own sport	.119	-.007
Skill: Other sport	.255	.066
Liking	-.066	.134

* p < .05

Discussion

Experiment 3b tested whether having a prime image of the context followed by the athlete stimulus would provide the cues needed to modulate the embodiment of the expected actions of famous athletes. It was hypothesised that the negative compatibility effects should be stronger when the athlete is seen in their typical situation (e.g., on a football pitch), where they would be expected to perform these actions, compared to an atypical situation (e.g., at a wedding), where such an action expectation is reduced. This would support the previous claim that both person and situation are crucial to embodied behavioural predictions of others. However, the results, again, favoured the hypothesis that embodied components of person-knowledge are only activated when there is uncertainty, that is, when the athletes are seen in an atypical context. Such person-specific effects would not be predicted by stimulus response accounts.

As with Experiment 3a, the current data replicate previous findings that viewing athletes famous in their sports influenced observer motor systems (Bach & Tipper, 2006; Tipper & Bach, 2011), even if the athletes were not shown performing their typical actions. Numerically, the results replicated Experiment 3a that participants showed negative compatibility effects when the athletes were not performing their sport (i.e., slower to identify Andy Murray using a hand compared to a foot response). As in Tipper and Bach (2011), these effects were reduced when viewing the athletes performing their typical actions, to the point of showing facilitation effects. These findings suggest that merely seeing Andy Murray elicits the expectation that he will use his arm. This priming facilitates responses with the same effector when observers see him performing as expected. In contrast, when he is not performing his expected action, this appears to be coded as an absence - a negative deviation of an action that was expected – and elicits negative compatibility effects.

As with Experiment 3a, the results support the notion of person-specific internal models that predict the behaviours of others. Even though not task-relevant, participants activated action knowledge of the athletes and this biased their motor responses. This replicates the role of *who* is being observed from Experiment 3a (and previous chapters) in eliciting these effects. However, if it is true that people encode which actions people typically perform in different situations (Barresi & Moore, 1996; Chapters Two and Three) then the athletes' typical actions should be expected specifically when they are shown in their typical contexts, where only these actions are appropriate. However, akin to Experiment 3a, the current experiment has not provided evidence for this hypothesis (but, again, sample sizes of over 1000 participants were found to be necessary to show the predicted three-way interaction). Instead, the same pattern of results was seen irrelevant of context, and the interaction of Action and Effector Congruency was, if anything, stronger in the out of context condition. This highlights who was seen, rather than where they were seen, as a key driving force for these effects, demonstrating that person-knowledge is the most crucial factor with other cues such as motor knowledge and context only becoming activated during uncertainty.

General discussion

The current chapter tested whether seeing an athlete automatically primes the main effector used in their sport such that when a famous tennis player like Andy Murray is seen, the participants' own arm is activated, even when Andy is not currently acting with his arm. Essentially, the experiments investigated the influence of person-knowledge gained prior to the experiment, and tested whether this affects motoric ("mirror") representations of others' actions. Finding that the participants' motor system would, in some way, represent the not seen but predicted action of an observed individual would provide clear evidence for social predictions of others' actions, and would provide evidence that the prediction effects seen in previous chapters truly reflect anticipation of the forthcoming action, rather than other stimulus or response aspects that could be encoded in a non-social format. A fully factorial design further tested whether presenting the athletes in or out of their typical contexts influenced the extent to which positive and negative compatibility are seen. More specifically, it was hypothesised that both the positive (when the athletes are seen acting) and negative compatibility effects (when they are not seen acting) should be stronger when the athlete is in their typical situation (e.g., on a football pitch), where they would be expected to perform these actions, compared to an atypical situation (e.g., at a wedding), where such an action expectation is reduced.

However, this is not what was found. Both Experiments 3a and 3b replicated previous findings that viewing athletes famous in their sports influenced the motor systems of observers (Bach & Tipper, 2006; Tipper & Bach, 2011), even if the athletes were seen not performing their typical actions. As with Tipper and Bach (2011), and particularly in Experiment 3a, there were more negative compatibility effects for non-actions than for typical actions (e.g., participants were slower to identify the tennis player Andy Murray using a hand compared to a foot response). As in Tipper and Bach (2011), these were reduced for the typical action stimuli, even to the point of showing facilitation effects (particularly in Experiment 3b). Thus, when Andy Murray is observed, it is predicted that he will use his arm to hit a ball, which primes the motor system to activate one's own arm leading to faster responses when Andy Murray is seen performing that action, but slower responses when he is not.

Bach and Tipper (2006) previously interpreted these facilitation and contrast effects in terms of contrast effects in social psychology and inhibitory dynamics in neural networks. However, recent predictive coding models suggest they might reflect prediction of forthcoming actions, based on one's prior knowledge of the athlete (e.g., Hickok, 2013; Kilner et al., 2007). Seeing a famous athlete not performing their sport is coded as a prediction error relative to the expected action, such that the non-performance of the action is coded as an absence, a negative deviation, of an action that was expected.

As with previous chapters, these experiments highlight the person-specific nature of these predictions. Knowing that someone typically uses their hand or foot influences person identification even though it is not task-relevant. Experiment 3a provides further support for this person-specificity with the replication of Tipper and Bach (2011) that knowledge held by the participants about the athletes influenced the motor priming effects; those who had more knowledge, and rated the athletes as more skilled in their sport, showed the strongest motor priming effects. Thus, the more is known about someone, the greater the knowledge of their behavioural tendencies, and the more likely motor priming will be seen towards them. This expands prior research that person-knowledge leads to predictions, which create biases for action identification (see Chapters Two and Three) and attentional biases (see Joyce et al., 2015). It also builds on prior work showing general motor biases exist (Heerey & Crossley, 2013; Sartori, Betti, Chinellato, & Castiello, 2015), to specifically highlight the contribution of person-knowledge on these predictive motor biases.

Evidence of these person-specific motor biases also extends prior research that there are over-lapping neuronal populations for self-performed and observed actions (e.g., di Pellegrino et al., 1992; Ondobaka et al., 2012; Rizzolatti et al., 1996; Rizzolatti & Craighero, 2004; Wilson & Knoblich, 2005). It suggests that a similar overlap exists between actions that are performed and actions that are merely predicted based on prior knowledge about how an individual has behaved previously, such that the mere knowledge that Wayne Rooney typically kicks a ball is enough to bias an observer's own motor system. Thus, the data support the person-model hypothesis rather than a stimulus response account, which would not hypothesise integration of such person-knowledge. Similarly, as all stimuli were seen equally frequently, stimulus response accounts would not hypothesise differences in response times across stimuli.

Interestingly, the current experiments highlight action typicality of the athletes as a key driving force for predictions, with situation as an apparently less important cue. Whilst this supports the importance of action cues found in Tipper and Bach (2011), and extends these results from face to whole body stimuli, it contradicts Barresi and Moore's (1996) assertion – and findings from previous chapters – that actor and situation combine in the prediction of action. One reason for this may be that famous athletes are seen primarily as a tennis player or a footballer and so it is these actions which are most salient when knowledge about them is reactivated, rather than other action tendencies that are relevant when we are interacting with these individuals. Indeed, Hastie and Park (1986) demonstrated that once a coherent impression about someone else has been formed, perceivers are able to retrieve that impression directly from memory without consulting the specific episodes that led to its formation. In this case, the most salient impression is likely to be kicking the ball or playing tennis, which is what is primarily retrieved by participants. In contrast, the context they are in is much less salient/relevant, and so this does not have the hypothesised modulating effect.

The data (numerically) support the idea that when an athlete is seen (e.g., Andy Murray), a specific person-knowledge heuristic is initially activated for him akin to opening an 'Andy Murray' folder on a computer. However, the details held within it are only activated (or 'read' in the computer analogy) if the situation requires it. For example, in the current task participants simply had to identify the athlete, thus this should have been easier (i.e., more predicted) when Andy was seen on a tennis court irrelevant of whether he was acting or not because this is where we would most expect to see him. In contrast, this task should have been more difficult if he was presented in a different situation like on the beach. The results tentatively suggest that it is this condition in which person-knowledge is ‘unpacked’, the Andy Murray heuristic (and the accompanying motor knowledge) is retrieved to help participants to resituate him.

This would be consistent with several other literatures that show a similar rapidly activated heuristic, the details of which are only released when the situation requires it. For example, it has been found that people only spontaneously partake in visuo-spatial perspective taking when they need to understand the situation better. Zwickel and Müller (2010) performed a dot-probe task with either a fearful or neutral face in the centre of the screen and participants had to say if the dot was on the right or the left. Participants only demonstrated perspective-taking – responding from the face’s rather than one’s own perspective – when presented with the fearful face, suggesting they took the perspective of the face to try to further understand the situation during fearful expressions, but not during neutral expressions when no further understanding was required.

Similarly, Butterfill and Apperly (2013) suggest a ‘minimal theory of mind’ whereby objects and agents can be ‘encountered and registered’ but not fully represented (e.g., in terms of attitudes, beliefs, etc.), which they suggest may explain the tracking of others’ beliefs under cognitive load or in infants/non-human species. As such, individuals can still make links between observed actions and goals without necessarily having to unpack the information or represent it fully, instead, only the outcomes need to be represented. This minimal theory of mind can only function for simple cases, with the full-blown theory of mind being needed for more complicated situations.

Taking a second look at Chapter Two in light of this, the reason context may have been more important in this paradigm may have been the task. In Chapter Two participants had to identify the action, thus it is unsurprising that there was unpacking of this person-knowledge to include situation. Here, seeing a ball or a computer and knowing that John tended to kick the ball but turn from the computer is helpful to the task. Also, of course, in Chapter Two the situation (i.e., object) was much more inherently related to the action – it provided affordances – so this definition of situation may be stronger in terms of predictions than a more general context with other (potentially distracting) information.

Taken together, the evidence in this chapter suggests that the three factors previously found in Chapter Two (actor, action, situation) may not be of constant equal weighting. Instead, the models may be primarily person-and-situation based, with other information (motor knowledge) only becoming activated when it is needed to aid understanding. However, there are several limitations with the current paradigm.

First, the stimuli were constrained to just two photographs in each category for each athlete due to difficulties finding the athletes performing their typical action out of context (and out of the context of their sports kit which could also have been influential), whilst still maintaining a high enough resolution and large enough photographs to clearly see their faces.

Second, there was a limited measure of how much experience the participants have with the athletes, and how much their (dis)liking for the athletes may have biased their perception. Due to its influence on the motor effects (see Experiment 3a and Tipper & Bach, 2011), this is an important area for future research.

Third, the use of foot pedal and keyboard responses may have further weakened the results. For example, there is some evidence that automatic imitation effects are stronger when the same effector is used to perform the action compared to a different effector (Heyes & Leighton, 2007). Moreover, mirror areas in the premotor and parietal cortices are activated in an effector-specific way (Buccino et al., 2001). However, there is limited information as to whether the specific movement with the effector is important. For example, does seeing someone kicking a ball just prime the observer's foot and leg so that they are ready to make any other movement, or does it prime the foot and leg specifically to make a kick? If the latter is true, then much stronger effects should be seen when the participant themselves must make a kick action rather than just pushing down on a foot pedal to identify the athletes. Recent developments in technology (such as the use of the Microsoft Kinect Sensor) could help to answer this question in future studies (see Chapter Five).

Conclusion

The current chapter investigated the influence of prior knowledge about the internal person-models re-activated during action observation, and whether the resulting actions are encoded in an embodied format. The findings partially replicated Chapter Two in that person-specific internal models were reactivated when the actor was reencountered. Crucially, the evidence suggests that these effects really are action-specific, leading to motor biases, thus supporting the proposition (see Chapter Two) that person-specific internal models are created for the behavioural tendencies of others. However, there was no evidence that situation modulates these effects. This suggests that the different cues thought to be important for making predictions (action, actor and situation; Barresi & Moore, 1996, Chapter Two) may have different weightings in different situations and tasks. Indeed, the hypothesis most supported by the current data is that observers automatically activate person-specific information, but that the details of this – whether a person is typically someone that uses their hands or feet – are only made available if further processing is needed to resolve uncertainty.

Chapter Five: An investigation into person-models in more naturalistic settings using the Microsoft Kinect Sensor

The previous chapters have provided evidence that person-specific internal models based on prior actor behaviour in a given situation are reactivated during action observation. However, as highlighted in Chapter Four, predictive coding accounts (e.g., A. Clark, 2013; Kilner et al., 2007) would suggest that predictions not only lead to such perceptual facilitation of others' expected actions, but that they could also "stand in" for perceptual input to form the basis of subsequent own behaviour, thereby leading to motor biases in one's own responses.

As discussed in Chapter Four, previous research has already demonstrated that the motor system can be activated when observing others, and reflect action knowledge about them. When seeing the faces of famous athletes, observers automatically re-activate general action-related information about the individuals, such as the body parts used in the sport of famous athletes (Bach & Tipper, 2006; Tipper & Bach, 2011), people's last emotional expressions, last direction of their gaze (Frischen & Tipper, 2006; Halberstadt et al., 2009), or the objects they typically look at (Joyce et al., 2015).

Studies have also found general motor biases based on prediction in general perception. For example, there is evidence for motor (and attentional) biases towards high probability trials using simple left or right arrow stimuli (Eickhoff, Pomjanski, Jakobs, Zilles, & Langner, 2011; Jakobs et al., 2009), or letters mapped to specific responses (Miller, 1998).

Various studies have also demonstrated more direct prediction effects within the motor system, which act as a sort of 'social affordance' and elicit appropriate actions in response to the other person. For example, there is evidence that whilst participants mimicked ‘polite’ smiles reactively, they displayed predictive smiles in response to anticipated genuine smiles of an individual (Heerey & Crossley, 2013). EEG data has even shown evidence for anticipatory motor simulation of a partners’ actions in a joint action task where one participant had to pass an object, and the other had to receive the object (Kourtis, Sebanz, & Knoblich, 2012), which is modulated by social factors such that it is stronger for a known interaction partner than someone participants do not have to interact with (Kourtis, Sebanz, & Knoblich, 2010). Moreover, a recent study found evidence for predictive motor biases in action observation (Sartori et al., 2015). Here, TMS and electromyography were combined at various time points to explore corticospinal excitability to the presentation of a football player acting out various penalty kicks. They found modulation of this excitability dependent on effector and time, and demonstrated evidence for kinematic, predictive and response coding, which can co-exist to some extent. For example, observing just before the run phase provided evidence of motoric predictive coding, then kinematic coding was found during the first phase of the kick, and finally motor activation was only present during the final phase of the kick. This demonstrates how three different levels of motor coding occur depending on which part of the action is currently being observed.

However, research into these predictive biases to date tends to investigate general effects, or those elicited by immediate social cues, and therefore do not consider person-specific knowledge within social situations, for example, that John might typically behave kindly towards a homeless person whereas George may ignore them. Chapter Four found preliminary evidence for person-specific motor biases. When participants saw the footballer Wayne Rooney, for example, it automatically activated the knowledge that he typically kicks with his foot (despite this not being task-relevant). However, rather than facilitating foot responses, there were contrast effects such that participants were actually quicker to identify Wayne Rooney using a hand rather than a foot-based response. This replicated previous findings evidencing inhibitory motor biases based on person-knowledge (Bach & Tipper, 2006; Tipper & Bach, 2011).

One reason that this embodiment led to inhibition rather than facilitation may have been due to the artificial keyboard/foot pedal responses, which are not the same as kicking a ball or hitting a ball with a tennis racket. The activation created by person-specific motor knowledge may be very specific to the action (kicking, swinging a racket) rather than just generally priming the effector as a whole. As such, it may be that facilitation effects may have been seen if the same action had been performed (e.g., the participant actually had to kick rather than press a foot pedal). The other possibility is that observing an action might facilitate a complementary action (i.e., when face-to-face with someone, seeing them kick the ball to the left might lead to activations of the observer motor system to move to their right to receive the ball). Yet much of the action prediction literature focuses largely on keyboard-based responses, leaving open the possibility that current investigations may be quite far removed from responses in the real-world (when observations actually affect the observer).

Therefore, the current chapter further explores these person-specific motor biases based on the behavioural tendencies of individuals, but using more naturalistic responses to assimilate the findings with more ‘real’ world situations where there are, at least some, consequences to the observer. Here, prediction biases on the motor system were further investigated using the Microsoft Kinect Sensor to maintain the rigorous control of Chapter Two, but with more naturalistic responding. This enables the investigation of whether facilitation effects might be seen when observers must respond in a more meaningful way themselves.

There is certainly precedence for a person-specific aspect to motor biases as such biases have already been found not just for perception (as in previous chapters), but also for gaze. For example, in a gaze cueing paradigm, we have recently demonstrated that observer gaze is anticipatory based on the typical gaze of actors towards objects (Joyce et al., 2015). Moreover, Chapter Four provided preliminary evidence that person-knowledge is similarly influential in creating motor biases.

Experiment 4: measuring social action predictions using the Microsoft Kinect Sensor

A key issue with the action prediction literature is that it is often far removed from reality; generally studies involve hundreds of trials using computers with simple button responses. Similarly, much of the social literature involves measurements that are often ambiguous and subjective, like simply reading descriptions about target people. Often merely the reading time of these descriptions is assessed (e.g., Belmore, 1987), recall of behaviours (Heider et al., 2007), or recognition of whether congruent or incongruent behaviours have been encountered previously (e.g., Sherman & D. L. Hamilton, 1994). As such, both literatures would benefit from an objective yet unobtrusive (and inexpensive) methodology, which still allows for ecologically valid responses.

The Microsoft Kinect Sensor V2 with its depth sensing, 1080p colour camera, active infrared capabilities and large field of view (cf. Microsoft Developers, 2016) may afford such a paradigm. This sensor can record the skeletal data of up to six individuals (tracking 25 skeletal joints per person) simultaneously, providing scope to track the different movements being made during social interactions. There is huge scope for a wide variety of applications for the sensor but, here, only the potential use of the skeletal tracking is considered. By pre-determining the parameters of movements being investigated the sensor can provide the relevant data in a time-efficient and objective manner, reducing research degrees of freedom.

The concept of motion capture is not a new phenomenon (see Barnachon, Bouakaz, Boufama, & Guillou, 2013 for an example of this methodology and a brief review of some earlier attempts at motion capture), but often requires expensive equipment. There has been a recent surge in the use of the such motion capturing in various rehabilitation efforts, and the use of these sensors as clinical tools (e.g., Barzilay & Wolf, 2013; Chang, Chen, & Huang, 2011; R. A. Clark et al., 2012; de Albuquerque, Moura, Vasconcelos, Mendes, & Nagem, 2012; Summa, Basteris, Betti, & Sanguineti, 2013; Vista & Angeles, 2012). Moreover, the Microsoft Kinect Sensor itself has already been used to explore the recognition of a range of human poses (Shotton et al., 2011) and gestures (Biswas & Basu, 2011; Gonçalves, Rodrigues, Costa, & Soares, 2012), but this is the first time, to my knowledge, that the sensor has been used in an action prediction paradigm.

Whilst some coding is currently required to build the experiment and to communicate with the sensor, there are also some programs (compatible with Windows 8 64-bit and above) with a much more user-friendly interface that do not require experience of coding. For example, Kinect Studio enables the recording of actions, which can then be inputted into Visual Gesture Builder to ‘teach’ the sensor what constitutes a specific gesture such as a kick to the right. Multiple exemplar recordings of each gesture are amalgamated to better teach the software some of the variability within the gesture (e.g., different strengths of kick, different speeds and distances of kick), which can then be tested and assessed to see how well the software performs on novel recordings. This provides an objective measure every time the Sensor ‘sees’ the gesture. For the current experiment, the Sensor was trained to differentiate a left from a right kick, and a left and from a right ‘block’ (turning the foot to the side to block the ball).

Thus, Experiment 4 investigates action predictions using the Microsoft Kinect Sensor to track more realistic movements. This provides a preliminary test of the use of person-models to bias more naturalistic movements in the observer. Previous research has provided evidence of motor biases based on prediction within non-social stimuli (Eickhoff et al., 2011; Jakobs et al., 2009a; Miller, 1998), and with more social stimuli (Heerey & Crossley, 2013; Sartori et al., 2015), but none, to my knowledge, has thus far explored the hypothesis that such biases may be influenced in a person-specific manner. Chapter Four provided preliminary evidence that such person-knowledge does lead to predictive motor biases, but using more artificial responses. Thus Experiment 4 explored this using more realistic movements, which are more generalizable to ‘real-life’.

Stimuli consisted of a three-frame sequence of a forward-facing male or female who 1) stood with a ball, 2) stepped in towards the ball, 3) kicked the ball (either to the left, right or centre of the screen at a variety of angles). These images were shown on a large screen with participants stood in front of it, playing the role of a ‘goal keeper’ by moving either to the right or left with their feet to simulate blocking the ball.

In each trial, the ball could be kicked by one of two actors (John, Claire). As before, unbeknownst to participants, one actor would mostly kick to the right and the other to the left. As with the previous experiments, it was hypothesised that participants would ‘learn’ these behavioural tendencies such that when they see the person who kicks to the right, they should be faster to move to block that kick than one to the left. Thus, it was predicted that the action onset would be initiated sooner for kicks in the typical compared to the atypical direction for each actor.

Method

Participants

40 undergraduates from Plymouth University (21 females, mean age = 22.53 years, SD = 3.97; 33 right handed and 36 right footed) participated in exchange for course credit. Sample size was based on the previous paradigm in Chapter Two. One participant was excluded due to technical issues.

Initial gesture training

First, pre-recorded "exemplar" video clips for training the Kinect recognition database were made using Kinect Studio. These were of actors 'saving' the ball to the right or left represented with a step to the left or right with the foot pointed in that direction such that if a ball really was kicked towards them it would hit the side of their foot and thus not 'score'. These exemplars also included kick gestures to the right and left in case participants chose to save the ball using a kicking rather than a blocking action.

Static gestures (point-in-time snapshots of a gesture response signature as a 3D map/shape of a participant's skeleton) formed the gesture training database. This gesture recognition database was then embedded into a custom-made program to detect response gestures in real-time during the experiment with a good degree of accuracy based on the live output from the sensor. Gesture recognitions were expressed as confidence values from 0.00 to 1.00 (0.00 = gesture not detected, 1.00 = gesture definitely detected).

Material and apparatus

The experiment proper was controlled by a custom-made program in Microsoft C#.NET making use of the Microsoft Kinect v2 SDK programming API for Kinect V2 sensors (“Developing with Kinect”, 2016). The experiment was displayed on a large-format (40”) flat screen TV at 1080p resolution to make the stimuli more life-sized and easier to interact with the Microsoft Kinect V2 Sensor at the base. The sensor was connected to the controlling laptop, which was Windows 8.1 64-bit with an Intel Core i5 processor and 6GB of RAM and a screen size of 1366 x 768 pixels via a USB 3 connection.

The stimulus set consisted of a series of three-frame sequences. The first frame was of a neutral photograph of the actor stood next to the ball, the second depicted a step-in towards the ball, and the third showed the actor kicking the ball. Each actor had 24 different final action photographs in total (12 depicting the actor kicking to various angles towards the left of the screen, and 12 to the right). Unbeknownst to participants, one actor would kick to one side 80% of the time and to the other side only 20% of the time, whilst the other actor would do the reverse.

An exit questionnaire asked participants to rate how much each actor liked the ball on a scale from -4 to 4 with no zero point. Then five further questions identified explicit awareness of the covariations. They were first asked “How easy did you find the task?” on a scale from 1 “really difficult” to 10 “really easy”. They were then asked whether they found it easier to identify the direction of the kick for one actor, and whether they found it easier to kick in one direction themselves. They were then asked if they noticed anything unusual about the actors or objects, and whether they noticed any patterns in the stimuli. They were then told one of the actors tended to kick the ball to the right and the other to the left, and were asked which one they thought was which (they were asked this question both in text and, later, by seeing a photograph and drawing an arrow to make sure there was no confusion between what counted as a ‘left’ and what counted as ‘right’).

Procedure

Participants received written and verbal instructions about the task. They were additionally asked to remove their shoes to prevent the weight of the shoe from hindering their movement, and to ensure as natural a movement as possible. After receiving a brief demonstration of the movement, they then carried out a minimum of two practice trials per actor; one straight kick and one extreme kick in the typical direction for each actor. If they were still unsure of the task, then they could complete further practice trials (which only one participant did).

When the experimenter was satisfied that the task was understood, participants completed the experiment proper, which contained 240 trials. The trials were presented in two blocks of 120 (48 trials in the typical direction and 12 in the atypical direction per actor) to ensure a more equal distribution of oddball trials throughout the experiment. At this half-way point, participants could take a short break before continuing with the second half of the trials.

Each trial started with a fixation cross in the centre of the screen (400-800 ms, randomly chosen) followed by the neutral photograph of the actor stood with the ball (shown for 1000 ms). Here, the response timer and sensor started recording. Then participants saw the step-in photograph for 500 ms, and the kick photograph for 2000 ms. Participants were asked to respond as quickly and as accurately as possible. After 2000 ms, a blank screen was shown for 1500 ms (to allow participants to get back in position), and the sensor recording stopped (see Figure 5.1 for a schematic of the trial sequence). After the experiment participants completed the two exit questionnaires, were thanked and fully debriefed about the aim of the experiment.

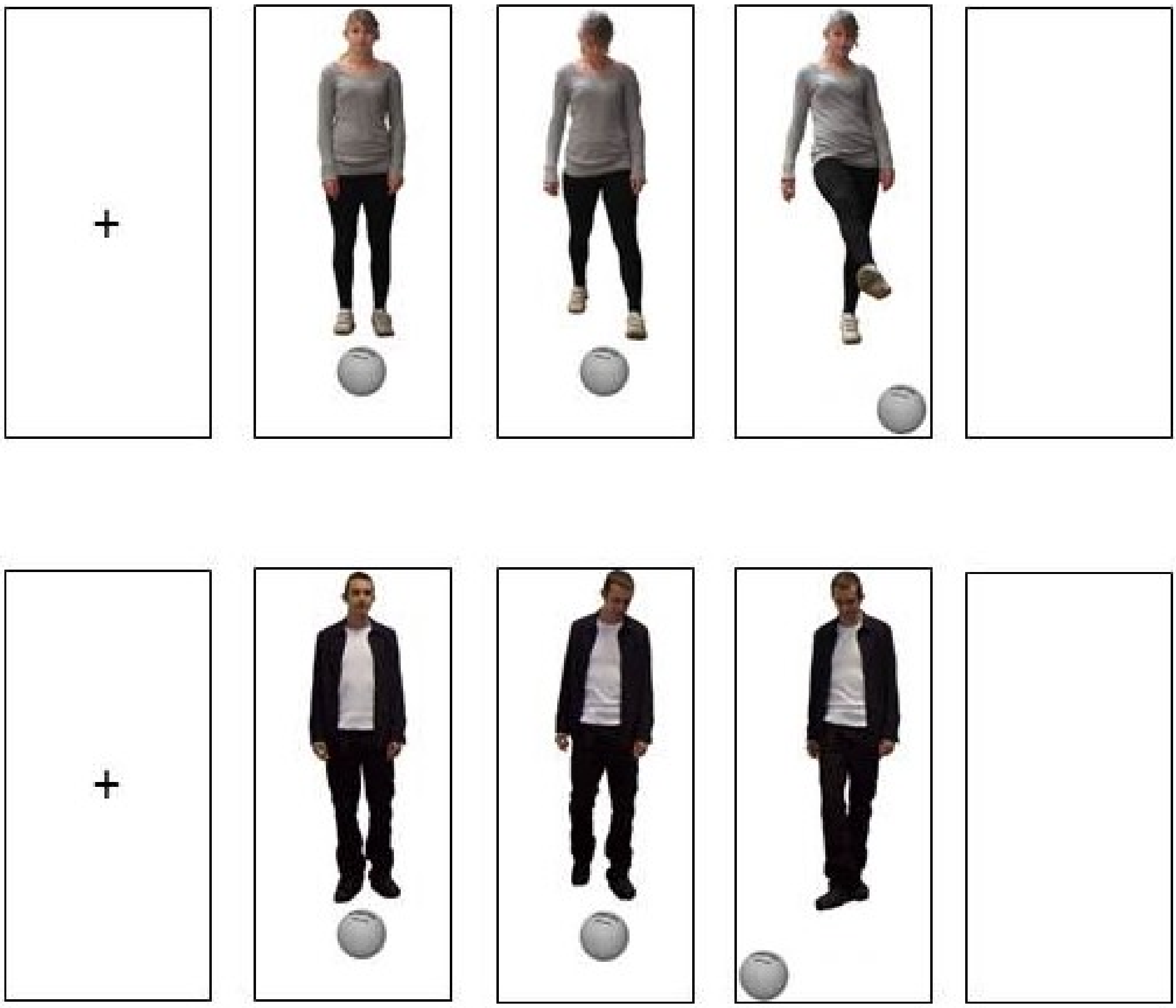

Figure 5.1. Schematic of the trial sequence for Experiment 4.
Each trial started with a fixation cross. Then the neutral image was shown with one of the two actors (*top*, Claire; *bottom*, John) stood in front of the ball. This was followed by an image of the actor stepping in, and then the kick image was shown. A blank screen was then presented to enable repositioning back on the central cross ready for the next trial.

Results

Funnel debrief

Overall participants perceived the task as being relatively easy (mean ease = 8.13), with neither actor being perceived to like the ball more than the other (p = .63). Neither direction was perceived as being easier to identify for one actor, but most participants reported it being easier to kick towards the right (*n* = 25) than the left (*n* = 10) or had no preference (*n* = 5), which is unsurprising given that most were right-footed.

Most participants alluded to some form of the manipulation during the funnel debrief (19 [47.50%] when asked if they found it easier to identify the direction of one actor, 1 [2.50%] when asked if they noticed anything unusual about the stimuli, and 7 [17.50%] when asked if they noticed any patterns in the stimuli). When informed of the manipulation, most participants selected the correct option (*n* = 33 [82.50%] for the worded version of the question and n = 34 [85.00%] for the pictorial version of the question).

Kinect data preparation

The data from the left and right feet were collapsed to give an overall dataset for both feet combined. As the centre of the room represents zero on the sensor, all negative scores were reverse scored to make the trials in both directions comparable. As in previous experiments, error trials (when participants went in the opposite direction to where the ball would have been kicked such that they would not be able to block it) were excluded.

The data were collapsed into trials in which the actor kicked in the direction that was typical for them and the direction that was atypical for them. Data were then split into five time points of approximately 500 ms (approximately one time point for the neutral stimuli, one for the step-in stimuli, and three for the action stimuli). Timings were approximate as timing within the sensor is only accurate to within two frames of recording (66 ms). T tests comparing the typical and atypical trials were then performed at each time-point with a corrected alpha of .01.

X coordinate scores

Data were first analysed based on the x coordinate scores (along the horizontal plane of the sensor) for both feet combined (see Figure 5.2). Here, movements occurred earlier (and to a greater extent) when they were in the typical compared to the atypical direction for that actor. Thus, it appears that participants learned that one actor tended to kick in one direction, and were using this in a predictive manner to prepare their own responses as they were faster to make the corresponding movement when it was typical compared to atypical for the actor. This prediction effect was seen significantly (according to the corrected alpha of .01) from approximately 1500 ms after the start of the trial (i.e., during the step-in photograph), thus suggesting participants had already begun planning their movement before the kick was even observed.

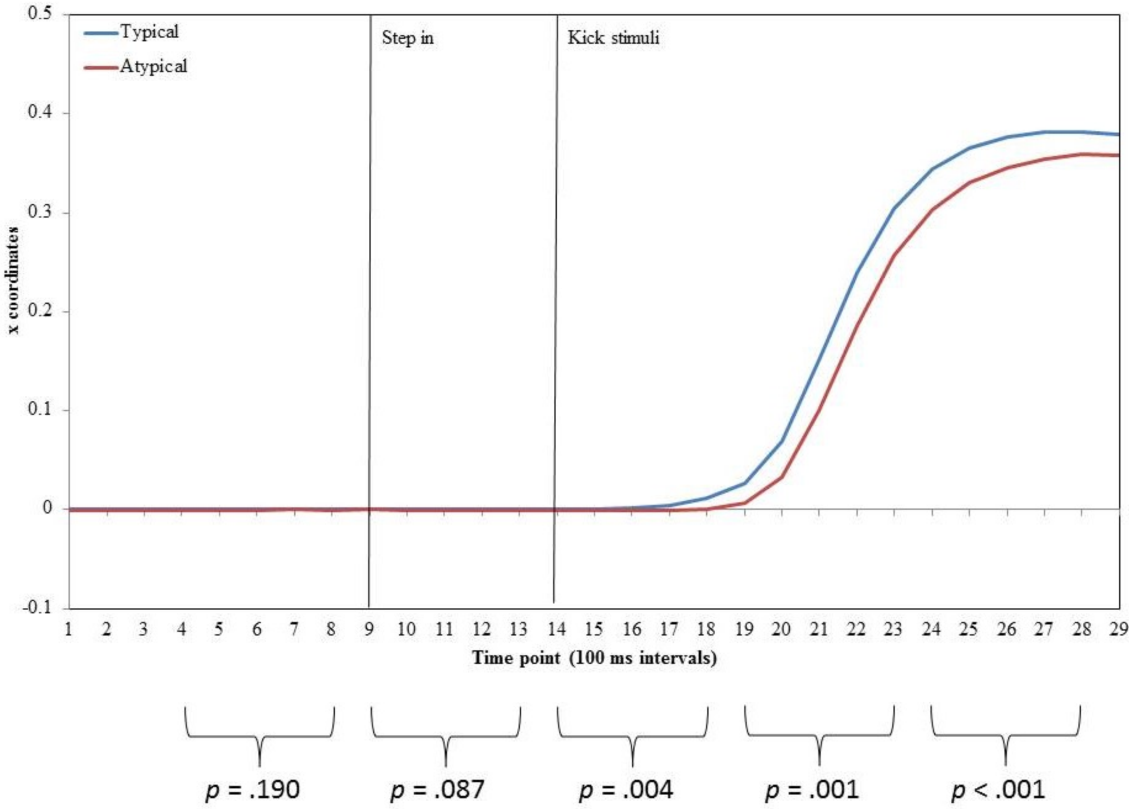

Figure 5.2. x coordinates for Experiment 4

A line graph showing the x coordinates for both feet combined based on whether the movement was in the typical or atypical direction for that actor over the duration of the experiment. Each time point represents approximately 100 ms, with time accurate to 66 ms. The table below where there were differences between typical and atypical trials according to the t tests carried out at each 500 ms time interval.

Confidence scores

For the confidence scores based on the gesture database (see Method Section), both feet were, again, combined, but for this analysis a threshold for each participant first had to be calculated where the recognition database was 50% confident that the gesture had been observed. This was achieved by, first, averaging the confidence scores for each participant and, second, finding the time point where maximum confidence occurred for each individual. As can be seen in Figure 5.3, the kicks tended to be given a higher confidence score if they were in the typical compared to atypical direction for that actor. The analysis, indeed, revealed that the recognition database was able to recognise the typical actions sooner (on average in the 22nd time interval; $M = 22.47$, $SD = 1.54$) than atypical actions (on average in the 23rd time interval; $M = 23.13$, $SD = 1.14$), $t[37] = 3.696$, $p = .001$, $d = .49$. Thus, the recognition database was more confident (i.e., able to define the kicks) at an earlier time when they were in response to the typical direction of the actors (approximately 2400 ms from the start of the trial), than when they were in response to the atypical direction (approximately 2500 ms from the start of the trial).

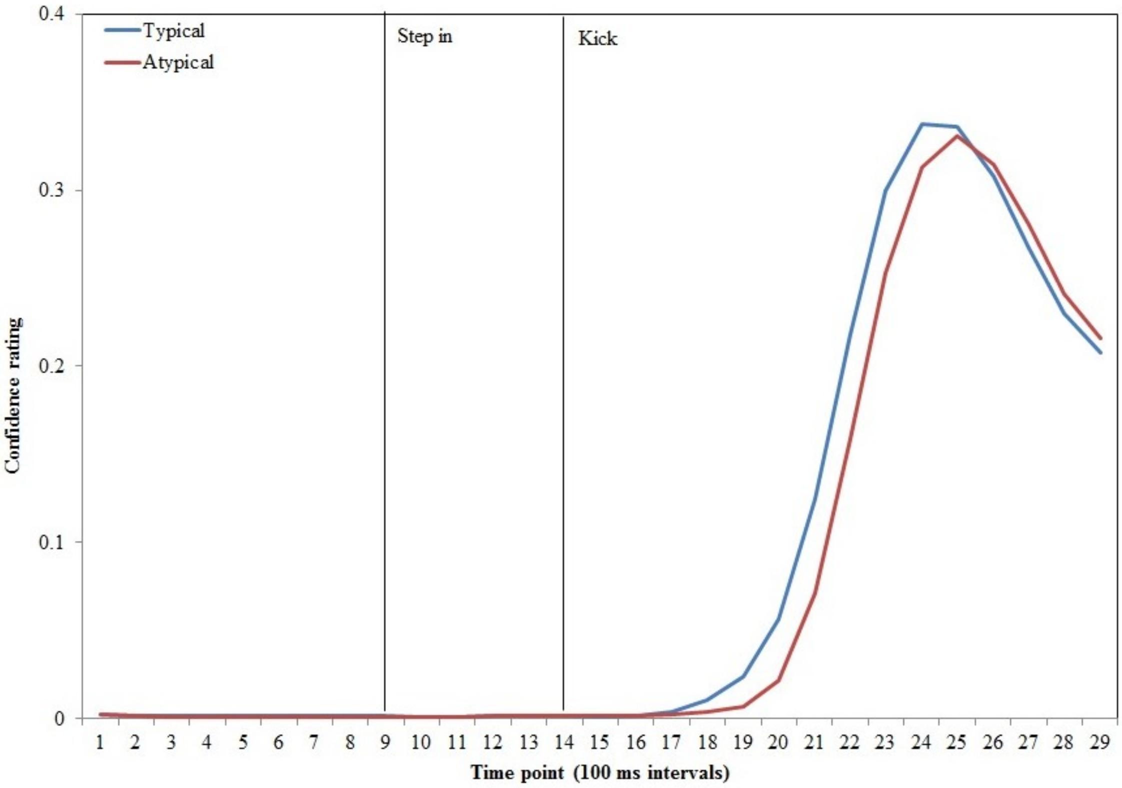

Figure 5.3. Confidence scores for Experiment 4
A line graph showing confidence scores for both feet combined based on whether the movement was in the typical or atypical direction for that actor over the duration of the experiment. Each time point represents approximately 100 ms, with time accurate to 66 ms.

Discussion

The current chapter investigated evidence for person-models in more ecologically realistic settings. Prior chapters have evidenced person-models, but using rigorous laboratory methods that are far removed from everyday life. Whilst such paradigms have high internal validity due to the high levels of control, and reduction in potential confounding variables, they leave open questions about the generalisability of the findings both across paradigms, and to real-life. Whilst several iterations of the paradigm have been tested, with results seeming to generalise at least to some extent, the current chapter is the first to attempt to assimilate these paradigms into situations more akin to real-life.

Experiment 4 utilised the Microsoft Kinect Sensor to assess motor biases based on person-models using more natural responses. This experiment, therefore, tested whether predictions about how individuals will act, derived from their previous behaviour, can drive own responses in joint action. Put another way, it tested whether predictions can 'stand in' for real behaviour and drive own responses as if the predictions themselves were actually perceived. Instead of the keyboard responses from prior chapters, participants simulated a more 'real-life' exchange by responding to actors kicking a ball by 'acting like a goalkeeper' and blocking it as they would if they were playing football in the park. Thus, this provides a preliminary test of whether the prior findings can generalise to more realistic responses, and, indeed, what happens when there are more 'real-world' implications for the participant. It also tested the potential application of the Microsoft Kinect Sensor to assimilate action prediction paradigms into more ecological settings, whilst still maintaining objectivity and relative precision of responses.

As predicted, participants were faster to 'block' to the right if this was the direction that the actor tended to kick towards compared to if they tended to kick towards the left. As such, it provides further evidence that person-models are created and used to make predictions about future actor behaviour, this time using more naturalistic responses (Barresi & Moore, 1996). Thus, the evidence suggests that predictions about other people's behaviour was used for own responses when participants had to 'block' the balls. Actions were initiated earlier, and movements were more pronounced, when they were made in the direction that corresponded to the actor's prior behaviour. This generally happened even before the action stimuli had been displayed, or very early into the action stimuli. Contrary to previous experiments in this thesis, participants could explicitly identify the experimental manipulation both spontaneously, and from more cued questions.

These results provide further evidence for person-specific internal models that are (a) created based on the behavioural tendencies of individuals, and (b) reactivated to predict forthcoming actions. This builds on our previous research demonstrating how such predictions based on person-models bias action observation (see Chapters Two and Three) and attention (Joyce et al., 2015), to include biases on motor responding (see also Chapter Four). These findings, again, support the theory put forward by Barresi and Moore (1996) that we create ‘intentional relations’ between people, objects and actions, and Newen's (2015) theory that person-models are created based on prior knowledge of the individual.

These data support the hypothesis that predictions of others’ behaviour can ‘stand in’ for real actions, and guide our own behaviour in social situations (e.g., A. Clark, 2013; Kilner et al., 2007). Being able to accurately predict other people’s behaviour enables us to prepare our own responses to enable more fluid and successful social interactions.

Experiment 4 extends previous research demonstrating that observers automatically re-activate general action-related information about others, such as the body parts used in the sport of famous athletes (Bach & Tipper, 2006; Tipper & Bach, 2011), people’s last emotional expressions, or direction of their gaze (Frischen & Tipper, 2006; Halberstadt et al., 2009). The current findings also support the experiments in Chapter Four that suggested that we can create person-models for typical actions of others, and this can influence our own responding.

It also builds on other prior research showing evidence of predictions biasing motor responses more generally (Eickhoff et al., 2011; Jakobs et al., 2009b; Miller, 1998) and specifically within social paradigms (Heerey & Crossley, 2013; Sartori et al., 2015), to specifically highlight the influence of person-specific knowledge on these biases.

Experiment 4 also supports the importance of prediction in joint action (for a review see Sebanz et al., 2006). For example, research has shown that we represent a co-actor's action in advance to enable a smooth coordinated behaviour with them (Kourtis et al., 2012), and that shared representations are formed for co-acting individuals dependent on how the social situation was conceptualised (Sebanz, Knoblich, & Prinz, 2005), with different aspects of visual information (whether to focus on the body or the racquet of a table tennis player for example) being modulated by the social context of whether a cooperative or competitive action is required (Streuber, Knoblich, Sebanz, Bülthoff, & De La Rosa, 2011).

Limitations and open questions

A key divergence between Experiment 4 and the prior research in this thesis is that the person-models here appear to be much more explicitly accessible. As such, it is unclear to what extent the mechanism is the same as in these previous paradigms, and the extent to which the data reflect controlled strategies of participants.

One explanation for the current prediction effect not being implicit may relate to COVIS models (e.g., Ashby et al., 1998; Maddox & Ashby, 2004). Such models suggest that patterns that can be verbalised are controlled explicitly. Here, the design is much more simplistic; situation was constant and only direction of action changed between actors. As such, the current person-models were much easier to verbalise (e.g., he goes left, she goes right). However, in previous paradigms the person-models varied on two counts (actor *and* situation), thus they were less easy to verbalise. Thus, in line with COVIS models, implicit learning was apparent. Interestingly, when these person models are actually explicitly verbalised to participants (see Experiment 1c), there is, again, evidence of explicit strategic responding.

Another outstanding question from the current data is whether the predictions are perceptual (i.e., ‘seen’ in the mind’s eye, which then alters the motor response), or whether these predictions act directly on the motor system. Participants’ apparent explicit awareness would suggest that direct motor biases are probably less likely in the current paradigm. Nonetheless, Chapter Four highlighted how predictions can become embodied within the observer and lead to motor biases.

Finally, the current experiment cannot differentiate between the person-model hypothesis and stimulus learning accounts. But see Chapters Two, Three and Four for some evidence against stimulus learning accounts.

Highlighting the use of the Microsoft Kinect Sensor as an objective measure, the confidence scores matched the x coordinate findings in that kicks in the typical direction were rated by the recognition database as more confident that the gesture had occurred, and that this gesture was initiated earlier in time. This establishes the sensor as a more naturalistic yet objective tool for action predictions. Indeed, a variety of investigations corroborate the accuracy of the Microsoft Kinect Sensor to track and detect a variety of gestures (e.g., Biswas & Basu, 2011; R. A. Clark et al., 2012; Gonçalves et al., 2012; Kar, 2010; Obdrzálek et al., 2012; Ren, Meng, Yuan, & Zhang, 2011).

Now that the Microsoft Kinect Sensor has been successfully established as an objective measurement tool, it can be tested in further paradigms. To test the COVIS approach to learning, future research could adapt Experiment 4 to vary both actor (male, female) and situation (e.g., football, tennis). Here, the person-models should be less easy to verbalise and thus, in line with COVIS models (and prior research in this thesis), learning should be more implicit.

Another key avenue possible with the sensor is to allow action predictions to be tested in more naturalistic settings rather than relying on mere button responses. For example, future research could also incorporate virtual reality into the paradigm to create an even more immersive and naturalistic setting. Here, consequences to the participant would even further simulate ‘real-life’ as they could react to a virtual ball actually moving towards them, and see the results of their own action simulated within virtual reality. This is an important avenue for future research because, as previously mentioned, responses may differ when there are actual consequences to the participant, and when the situation is more akin to reality than the artificial setting of a computer screen with a simple button response. Based on the apparent robustness of the person-models demonstrated thus far in the thesis across multiple paradigms, I would hypothesise that person-models should also be apparent under these more naturalistic conditions.

A further question for future research would be to test competitive vs. cooperative situations to identify how the use of person-models may vary. Whilst there is certainly evidence that cooperative and competitive behaviours have different action patterns (Georgiou, Becchio, Glover, & Castiello, 2007), there is currently little evidence (to my knowledge) as to whether this kinematic information is used differentially whilst making action predictions. It may be, for example, that during a cooperative act you may pay more attention to the step-by-step actions required by both you and your interaction partner to achieve your joint goal. However, in a more competitive task, there may be looser, more holistic predictions on how they will act to achieve the goal, but the individual steps they take to achieve it may not be important. For example, given the task of putting together a table in the fastest time possible, you need to work closely with the other person to make sure the parts are aligned correctly to screw in the bolts, etc., but to put together a table faster than a competitor you simply need to ensure that your actions are faster than their actions. Thus, you need only monitor their overall performance, but not the individual steps of how they are aligning the different parts together.

Finally, another area for future research is to identify just how specific predictive motor biases (and embodiment) may be. For example, does observing a kick activate the leg in general, or specifically a kicking movement? Such examinations have previously been limited due to a lack of (affordable) technology. Now, with the Microsoft Kinect Sensor, these research questions can be addressed in a more cost-effective manner. For example, the experiments of Chapter Four could be altered such that participants have to respond to identifying the athletes by using either a kicking or hitting response. Under these conditions, it may well be that the negative compatibility responses were merely due to basic effector inhibition, but the actual action might be primed. Thus, the hand might be specifically prepared for a hit, not a button press.

Conclusion

The current chapter explored the potential for motor biases based on predictive person-models in more naturalistic settings. The results provided further evidence for predictive motor biases based on person-models for motor responses. Moreover, the Microsoft Kinect Sensor has been shown to be an effective measurement tool within an action prediction paradigm, with wide scope for applications in a variety of different paradigms.

Chapter Six – An investigation into person-models in more naturalistic settings using a mimicry paradigm

A vast array of evidence demonstrates that people adapt their behaviour to copy their interaction partners. However, the majority of research investigates 'responsive' mimicry. For example, if I touch my face, my interaction partner has a tendency to also touch their face (Chartrand & Bargh, 1999). If I use certain words, my interaction partner utilises the same specific terminology such as saying 'spuds' rather than potatoes (for a brief review see Lakin et al., 2003). If I use an object in a certain way, my interaction partner also uses it in the same way. This automatic matching of one's own bodily states to those of interaction partners is heavily supported across the literature (e.g., Brass et al., 2000; Chartrand & Bargh, 1999). The current chapter builds on this literature to investigate whether there is a 'predictive' aspect to mimicry.

For social interactions, mimicry serves various functions. Not only does observing (and imitating) others help us to learn, it has also been shown to enhance social cohesion (e.g., Chartrand & Bargh, 1999). For example, mimicry can communicate similarity to an interaction partner (e.g., Gueguen & Martin, 2009). Here, mimicking someone shows them that "I am like you" or, for the purposes of someone observing you, "I am like them" (Over & Carpenter, 2011). Being mimicked also demonstrates "you are like me", and may help to dissipate tension/threat. There are also many other positive outcomes associated with mimicry (e.g., increased liking and rapport; Chartrand & Bargh, 1999; Lakin et al., 2003; Vrijsen, Lange, Becker, & Rinck, 2010, prosocial behaviour; van Baaren & Holland, 2004; Lumsden, Miles, Richardson, C. A. Smith, & Macrae, 2012, and more trust; Over, Carpenter, Spears, & Gattis, 2013).

Mimicry can also increase synchrony between interaction partners, for example, during joint action (Sebanz et al., 2006), and may enhance understanding of a situation by activating the same motor systems within the observer. Finally, mimicry may be used in a communicative manner, for example, to communicate to someone that you are empathising with them. Indeed, a study by Bavelas et al. (1986) demonstrated that participants displayed increased motor mimicry towards an actor in pain who made eye contact with the participants, compared to an actor who did not make eye contact. In the latter situation, there was a marked decrease (or shorter duration of expression) suggesting that participants only mimicked the actor if they thought it would be beneficial (i.e., if they thought the actor would see them).

Mimicry has been found across a broad range of behaviours from body language (Chartrand & Bargh, 1999), to gaze (Frischen et al., 2007) to pain responses (Morrison, Poliakoff, Gordon, & Downing, 2007) to observed reactions to errors or inhibitive behaviours (Schuch & Tipper, 2007). Whilst it is largely assumed to be highly automatic - mimicry has even been found when interacting with a computer avatar (Bailenson & Yee, 2005) - research has suggested that it is intentional and goal-directed at least to some extent (e.g., Chartrand & Bargh, 1999). Indeed, Wang and A.F. Hamilton (2012) provide evidence that mimicry is not a purely bottom-up process. To be able to mimic seamlessly (and automatically) within such interactions requires a sophisticated system, which can rapidly react to new input. Their STORM model proposes that mimicry is controlled by social goals, and is a strategy for increasing social standing. Over and Carpenter (2013) similarly suggest this top-down influence on imitation is due to human dependence on group membership (i.e., that there is a “social side to imitation”; p1.), namely that social motivations (e.g., needing to belong to, and affiliate with, a group) drive imitation, which can explain how imitation is sometimes extremely faithfully, and other times more selectively, carried out.

There is suggestive evidence of mirroring cells in humans that may control imitation during action observation (Mukamel et al., 2010), with further supportive behavioural evidence that mimicry is at least under some top-down guidance. For instance, more mimicry is found towards people deemed to be more powerful (in adults; Cheng & Chartrand, 2003; Dalton, Chartrand, & Finkel, 2010, in children; Chudek, Heller, Birch, & Henrich, 2012), and towards in group than out group members (in adults, Bourgeois & Hess, 2008; in children, Buttelmann, Zmyj, Daum, & Carpenter, 2013). When primed with exclusion, adults will mimic a new interaction partner more, particularly if they are an in-group compared to an out-group member (Lakin, Chartrand, & Arkin, 2008), and children will imitate a model more faithfully (Over & Carpenter, 2009). Moreover, after reading a short person description, participants are more likely to mimic facial expressions of positively than negatively described people (Likowski, Mühlberger, Seibt, Pauli, & Weyers, 2008).

Further evidence that, even within children, mimicry is not a purely bottom-up process includes children not copying erroneous movements (Carpenter, Akhtar & Tomasello, 1998), and not mimicking an elaborate or inefficient movement when a simple movement would suffice (Gergely, Bekkering, & Király, 2002). Instead, it is the goal rather than the action that is mimicked. Over and Carpenter (2013) suggest that whether an infant (or presumably an adult) selectively or faithfully mimics depends on their goal (social, non-social, or an integration of the two). Thus, mimicry is influenced by social context and is not always automatic, even in children. If mimicry is a way of saying 'I am like you', it is unsurprising that mimicry occurs more towards those deemed more similar, or who we aspire to be.

Further support for a top-down influence on mimicry is apparent in those with echopraxia (automatic, uncontrollable tendency to imitate) and echolalia (unintentional repetition of another’s words). This ‘disordered’ mimicry is usually found in those with impairments in their ability to self-regulate consciously and intentionally including aphasia, apraxia, mental retardation and frontal lobe injury (e.g., Lhermitte, Pillon, & Serdaru, 1986). Indeed, research has shown that mimicry increases when resources are taxed in ‘normal’ populations (Dalton et al., 2010). Thus, under ‘normal’ circumstances there must be some form of regulator that prevents the mimicking of every single observed action. This is required for many successful social interactions, especially when cooperating with another person. As Sebanz et al. (2006) highlight, the common goal needed for successful joint action requires complementary (not identical) behaviours. In other words, whilst mimicry may aid our affiliation goals, if we wanted to move a heavy table together, it would not be efficient.

Together, these findings of top-down guidance in mimicry provide a basis for the assumption that it might also be predictive. Instead of simply aiding current interactions, it may be used to foster affiliation in future encounters. Much as with general social action prediction, predictions here would be based on person-specific models of how interaction partners have behaved in previous encounters (e.g., often playing with their hair, tapping their feet). This information would then be reactivated in a future encounter with the individual, and lead to pre-emptive hair playing oneself in the expectation that the individual will be performing that behaviour again to foster the ‘I am like you’ message.

There is already evidence for anticipatory responding to real rather than ‘polite’ smiles (Heerey & Crossley, 2013), which highlights the tracking of other people’s movements, and responding in an anticipatory manner during interactions. Experiment 5 goes one step further, hypothesising that if mimicry occurs during social interactions, and the behavioural tendencies of actors can be tracked, then there may be some form of mechanism for ‘predictive’ mimicry. Such a mechanism would ‘learn’ that John tends to tap his foot during an interaction, associate it with his internal person-model, and reactivate this information when he is seen again. As such it could ‘prime’ observer motor systems. Thus, when participants see John again, they will (1) begin tapping their foot as a result of this action being reactivated, even if John himself does not tap his foot (yet), and (2) assuming they (implicitly) wish to affiliate with John and reap the benefits of mimicry (briefly described above).

Whilst, to my knowledge, this has not specifically been investigated previously, there is evidence of ‘deferred’ imitation in infants. Generally, in these studies participants see actions with objects in a first session, and then their imitation of these actions with these objects is assessed in a second session. For example, Barr, Dowden, & Hayne (1996) found deferred imitation with a 24-hour delay between the first and second session in 12, 18 and 24 month old infants (and even 6 month olds provided they had additional exposure to the target actions). This was later supported by Collie and Hayne (1999) who found both 6 and 9 month olds produced more target than control actions following a 24-hour delay between sessions. Meltzoff (1988) even found deferred imitation after a one-week delay between sessions for 14-month-old infants.

Barnat, Klein, and Meltzoff (1996) demonstrated that deferred imitation does not require the same strict context and object conditions as during the original demonstration period (i.e., the mechanism is relatively flexible and adaptable). Compared to controls, infants still produced more target behaviours even when the objects were different colours or sizes, and even when the room in which they saw the objects was different to encoding. However, more imitation was found when these factors were consistent across encoding and retrieval. Moreover, Herbert (2011) demonstrated increased imitation when infants were given a verbal cue at encoding and retrieval compared to when they were given no such cue. This indicates that these acts create a stored representation, which is reactivated when a relevant cue is provided leading to facilitated recall of the behaviour. There is also evidence that infants produce tongue protrusions both in the presence of someone protruding their tongue, and when they meet this person later as though producing this from memory (Meltzoff & Moore, 1989). A later study (Meltzoff & Moore, 1994) found that this was not specific to tongue protrusions, but also to 'mouth opening'. Those infants who saw an adult protruding their tongue imitated this behaviour more during that interaction, and also produced this movement 24 hours later when they viewed the same face this time displaying a neutral expression. Similarly, those who saw the adult in the mouth opening condition, imitated this behaviour more during the initial session, and also performed this behaviour when later presented with a neutral expression. This indicates that the infants learned the behaviour (either tongue protruding or mouth opening), linked it to the representation of the other person, and reactivated this stored knowledge 24 hours later when they saw this person again.

Experiment 5: an investigation into person-specific 'predictive' mimicry

The experiments on deferred imitation demonstrate that participants do reactivate imitative actions in a second interaction. However, these behaviours were found in infants, goal-directed towards achieving an object-directed outcome, and associated with objects. Thus, they fail to examine the influence of person-specific models. However, there is some precedence for person factors being important here, with evidence that infants will imitate someone they deem to be more reliable compared to someone seen to be unreliable (e.g., Poulin-Dubois, Brooker, & Polonia, 2011). Experiment 5, therefore, aims to demonstrate that mimicry can be person-specific, such that participants perform the behaviour that their interaction partner has performed in a previous encounter.

To test this hypothesis, confederates performed one of two ‘model’ behaviours in an initial interaction with the participant (face touching, foot tapping), but during a second interaction with the participant they did not perform the model behaviour. Thus this paradigm tests, first, whether participants would mimic this initial behaviour as seen in previous studies (Chartrand & Bargh, 1999), and second, whether participants would (implicitly) predict reencountering this behaviour when they meet these individuals again and so continue performing the behaviour in a second interaction, even when the confederates no longer perform the actions themselves.

As a partial replication of Chartrand and Bargh (1999), participants performed a picture description task, first, together with one confederate who performed one model behaviour (e.g., tapping their foot), then with a second confederate who performed the other model behaviour (touching their face). They then met the first confederate again who, this time, did not perform the model behaviour. Finally, they met the second confederate again who also no longer performed their model behaviour.

It was hypothesised, first, that participants would mimic the model behaviour for each confederate during the initial encounter. In the above example, they would tap their foot with the first confederate, and touch their face with the second confederate (counterbalanced across participants). Second, it was hypothesised that participants would associate these behaviours with their interaction partners, thus would continue performing the behaviour specific to each confederate in a second interaction with them.

Method

Participants

40 first year undergraduate psychology students (all female, mean age = 18.88, SD = 1.16) participated in the study in exchange for course credit. Two participants mentioned that they thought the other ‘participants’ were confederates, and one other participant freely recalled the manipulation, so all three were removed from further analyses.

Design and materials

As with Experiment 3, the empathy quotient was administered. A creativity questionnaire additionally asked participants various questions about their musical and artistic talents to help with the cover story that the experiment was investigating video game use and creativity.

The Xbox Kinect game “Kinect Adventures” was used whereby two people (here the participant and a confederate) work as a team to knock down crates using their arms to direct balls. This, again, was part of the cover story for the aim of the experiment, and additionally it provided a collaborative environment to set the participants in a more collaborative frame of mind, and to bolster affiliation which has been shown to have a bi-directional relationship with mimicry (see Lakin et al., 2003).

The picture description task involved the participant and one confederate sat facing each other, taking turns to describe what was shown in the picture. They were told to try to construct a brief story about what was happening. To help make sure the task was performed correctly, the confederates always started.

The funnel debrief asked participants to rate various aspects of their interactions with each confederate on a Likert scale from -4 to +4 with no 0 point. These questions assessed how fluent the interaction was perceived to be, how much they liked the confederate, how good they thought the confederate was at the picture description task, and how well they thought they cooperated during the initial Kinect game.

The final exit questionnaire asked participants whether they noticed anything unusual about the behaviour of the other two ‘participants’. They were then asked if they noticed that one participant tended to tap their foot and the other touched their face and, if so, who they thought did each behaviour. Participants were then asked if they noticed they were tapping their foot more with one participant and, if so which one. Finally, they were asked if they noticed that they were touching their face more with one participant and, if so which one.

Procedure

Upon entering the lab participants were informed that they would be taking part in an experiment exploring the influence of real action video games on creativity levels. Participants first played the Xbox Kinect game for approximately five minutes (once with each confederate, and the confederates also ostensibly played the game together). During the game, the person not involved would leave the room.

Next, the first confederate and the participant did the first picture description task for seven minutes. The confederates would show their respective behaviours. Then the confederates swapped and the task resumed for another 7 minutes. Next, the participant left the room to fill out the creativity questionnaire and the empathy quotient whilst the confederates ostensibly did their 7-minute picture description task.

The picture description task was then repeated in the same order, but this time lasting only 3 minutes. The confederates were instructed not to perform their model behaviours here. Finally, the participants filled out the funnel debrief and exit questionnaire before being fully debriefed about the aims of the study. During this debrief they were asked what they thought the task was about, and whether they had noticed the two behaviours.

Coding

Each session was split into 30-second time intervals; thus, there were fourteen intervals for the first interaction and six for the second interaction with each confederate. The frequency for general movements with the arm and foot were calculated (based on personal correspondence from Chartrand, 18.11.15) for each participant during each time interval. This figure was then averaged across the time intervals to give an average rating across each of the four interactions. A rating was also given for the non-model behaviour (e.g., touching the face if the experimenter shook their foot) as a comparator in the same way. The same rating was given for only the specific movement (foot tapping, face touching) for each participant during each time interval.

Three coders performed these ratings on the first seven participants, and achieved high levels of intra correlation coefficient reliability (see Table 6.1), thus each coder then rated a third of the remaining participants.

Table 6.1

The intra-class correlations for the three coders for the first 7 participants for Experiment 5.

	Coders 1 and 2	**Coders 1 and 3**	**Coders 2 and 3**
General Foot	.911**	.996***	.938***
General Hand	.889**	.829*	.862**
Specific Foot	.754*	.814*	.960***
Specific Hand	.988***	.998***	.989***

*$p < .05$ ** $p < .01$ *** $p < .001$

Results

Funnel debrief

When asked if they noticed anything unusual about the other participants' behaviour, 27 participants (67.50%) said they did not. Of the remainder, most commented that at least one confederate seemed a little nervous, or that one or both confederates tended to perform the task very well, but two (5.00%) explicitly mentioned awareness of the task and were excluded from further analyses.

Twenty-five participants (62.50%) said they were aware of the movements and thirteen (32.50%) said they were not. Twenty-nine (72.50%) correctly stated the model behaviour for each confederate, but eleven (27.50%) were incorrect. However, when asked what they thought the experiment was about, only two (5.00%) alluded to mimicry in some form (and were excluded from the analysis as mentioned above), the rest gave answers around creativity and video games (e.g., in line with the cover story).

The only significant differences perceived between the first and second confederate overall was that the first confederate (counterbalanced across participants) tended to be rated as better at the task, t[39]= 2.314, p= .026. All other differences were non-significant (all t's $\leq$ .960). When comparing the two actual different confederates (irrespective of the order in which they were seen), there were no differences in perception of the cooperation, likability, fluency of the interaction, nor ability to perform the task between the two confederates, all $t < 1.275$.

Behavioural results

A repeated measures ANOVA was conducted with the factors Session (first interaction, second interaction) and Behaviour (model, non-model) on the coded data of general movements with feet or hands. The analysis revealed no main effects of Behaviour, F[1,36] = .574, p = .454, $\eta\rho^2$ = . 160, nor Session, F[1,36] = .174, p = .679, $\eta\rho^2$ = .174, and no interaction between the two factors, F[1,36] = .041, p = .841, $\eta\rho^2$ = .001.

A parallel ANOVA was conducted for the coding of just the specific behaviours (tapping the foot, touching the face). The analysis revealed a main effect of Session, F[1,36] = 7.179, p = .011, $\eta\rho^2$ = .166 with lower scores for the first (M = .58, SE = .06) compared to the second session (M = .75, SE = .09). However, there was no main effect of Behaviour, F[1,36] = .574, p = .454, $\eta\rho^2$ = . 160, nor any interaction between the two factors, F[1,36] = .041, p = .841, $\eta\rho^2$ = .001.

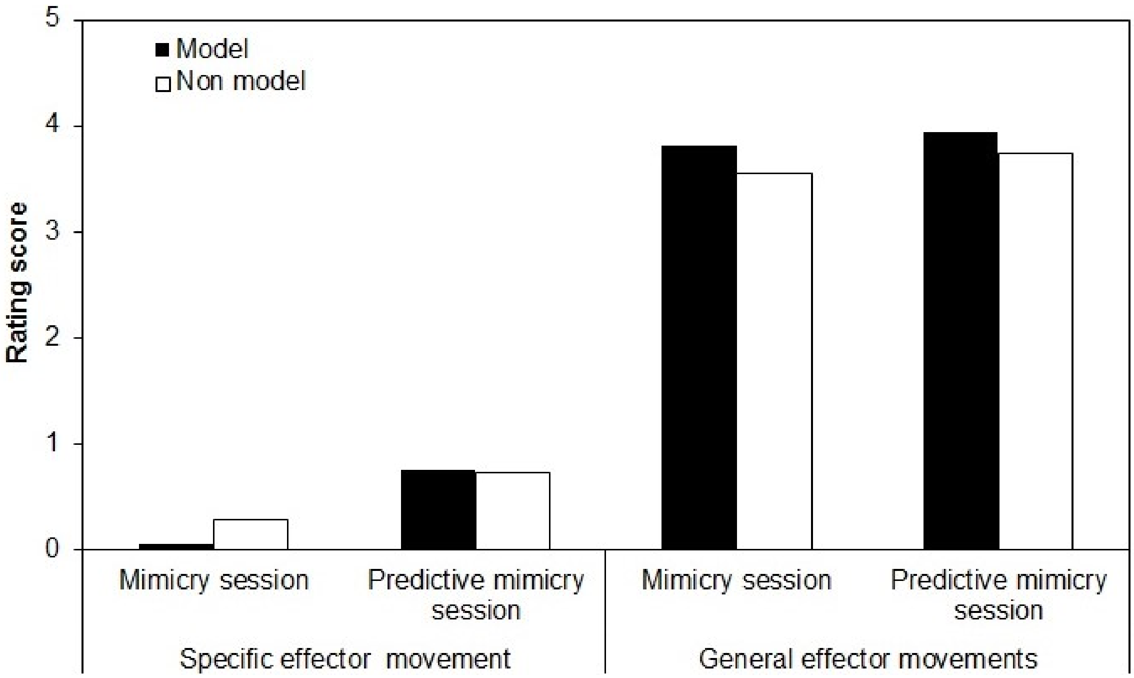

Figure 6.1. Coding ratings for Experiment 5.
The left-hand side shows the coding ratings for the specific effector movement (foot taps, face touching) and the right-hand side shows the ratings for general movement of the model effector (hand, foot). The black bars represent the model behaviour (the behaviour performed by the confederate e.g., foot movements) and the white bars represent the non-model behaviour (the other behaviour e.g., hand movements).

EQ correlations

Correlations were conducted on the difference between model and non-model behaviours for each session (first interaction, second interaction) and the EQ separately for specific and general movements of the effector. The analysis revealed no significant correlations between the EQ and behaviour for general movements in either the mimicry (r = .043, n = 37, p = .802), nor predictive mimicry sessions (r = -.264, n = 37, p = .115). However, there were near significant negative correlations between the EQ and behaviour for the specific movements in the mimicry (r = -.295, n = 37, p = .077) and predictive mimicry conditions (r = .076, n = 37, p = .092). This indicated that those with a higher EQ displayed fewer specific model movements. As research suggests that mimicry does not happen when participants are aware of it (Lakin & Chartrand, 2003), this lower model behaviour might be due to participants actively avoiding performing the same action as the confederate.

Discussion

The current chapter investigated evidence for person-models in more ecological settings. Prior chapters have evidenced person-models using rigorous laboratory methods, which are far removed from everyday life. Whilst such paradigms have stronger internal validity due to the high levels of control and reduction in potential confounding variables, they leave open questions about the generalisability of the findings both across paradigms, and to real-life. Specifically, Experiment 5 assessed the potential for a (person-specific) ‘predictive mimicry’ mechanism. It was hypothesised that participants would implicitly ‘learn’ the behavioural tendencies of their interaction partners (face touching, foot tapping), which would be reactivated when they met them for a second time. As such, this experiment aimed to investigate the potential for person-models to bias not just perception, but also motor responses. However, this experiment (as well as a similar preliminary study, see below) failed to find evidence for even basic mimicry, and thus predictive mimicry could not be investigated within this experiment.

One reason for this may have been that the ‘sweet spot’ for creating mimicry simply was not found. In a previous pilot, there was also no evidence for basic mimicry, but in this pilot the confederates made the movements approximately three times every ten seconds. However, in accordance with email correspondence from Dr. Tanya Chartrand (one of the original authors of the mimicry effect, 18.11.15), Experiment 5 consisted of almost constant movements. As such the movements may have been too obvious.

Indeed, three participants spontaneously mentioned performance of at least one model behaviour by one of the confederates. Moreover, most participants could accurately state which confederate made which movement, suggesting either that they were aware of the movements during the experiment or, as in previous paradigms (see Chapters Two and Three), could accurately relay information from their person-models to give the behavioural tendencies of the individual confederates. If the former is true then it is unsurprising that there was no evidence of mimicry given that it is not believed to occur if there is awareness of it (Lakin & Chartrand, 2003). Of course, it may simply be that mimicry is either not as ubiquitous in social situations as previously claimed, or that there is a high variability amongst individuals in the amount they mimic (and thus power was not strong enough in the current experiment).

Mimicry research, and observational studies in general, have a myriad of experimental difficulties. The biggest issue is in operationalising each movement. For example, there are lots of questions to ask when considering what constitutes a foot tap. Does a heel lift equate to a toe lift for example? Must the foot fully touch the ground? If both feet tap at the same time does it count as one or two foot taps? Etc. As such, it is very difficult to know what should constitute each model behaviour.

A further issue is that even when the behaviours in question have been operationalised, someone must then code these behaviours. This is not only incredibly time-consuming, but also very subjective. Typically, at least two ‘blind’ coders (individuals who are not told the aims of the experiment, nor the condition in which each participant is in) provide their measurements for each behaviour, and then this is averaged. Despite being unaware of the aims, it is often not particularly difficult to guess what is going on – particularly if the videos they are coding also show the confederates performing their movements.

One solution, at least for the coder subjectivity, is to use technology to do the coding. For example, Experiment 4 highlighted the potential of the Microsoft Kinect Sensor as an objective measurement tool for human actions (see Chapter Five). As such, it is possible that the sensor could be utilised in mimicry paradigms such as Experiment 5 to reduce the subjective (and time-consuming) nature of coding. Whilst there is still the complicated matter of deciding exactly what constitutes a model behaviour, once decided this could be 'taught' to the sensor to provide a more objective measure of whether these behaviours actually occurred, and to what frequency. The sensor could also be used in a similar manner in other observation-based experiments where there are clear and distinct behaviours to assess.

Conclusion

The current chapter explored the potential for motor biases based on predictive person-models during mimicry. However, Experiment 5 failed to provide the conditions necessary for even 'basic' mimicry of a confederate, and thus was unable to test for person-specific 'predictive' mimicry. As suggested above, the Microsoft Kinect Sensor may be an effective measurement tool to reduce potential subjective coding biases.

Chapter Seven – General Discussion

Social interactions are a major part of daily life, and are extremely dynamic. Successful social interactions may result from our ability to create accurate predictions for how our interaction partners will behave. Whilst prior research has focused on the use of available cues (e.g., emotional expressions; R. B. Adams et al., 2006, statements of intent; Hudson et al., 2016, action kinematics; Bach et al., 2011; Bach, Nicholson, et al., 2014) to make such predictions, the purpose of this thesis was to investigate the influence of prior knowledge about the person's typical behaviour. For example, Barresi and Moore (1996, see also Newen, 2015) theorised that humans create internal models of others' behaviour that describe the 'intentional relations' they hold towards objects. These internal models capture three key factors: who the person is, the situation they are in, and which behaviour they typically perform (and the mental states this behaviour implies). Whenever the individuals are seen again in a similar situation, this knowledge would be re-activated and provide information about their likely forthcoming actions, allowing efficient prediction of behaviour.

The current thesis utilised various paradigms to provide evidence for such predictive person-models during action observation (Chapters Two and Three), person identification (Chapter Four), and when acting together with others (Chapters Five and Six). The results, indeed, suggest that, as theorised by Barresi and Moore (1996) and Newen (2015), participants do form internal 'person-models' based on the behavioural tendencies of individuals in a given situation, which are reactivated when the individual is re-encountered in that situation again, and which influence action observation and one's own behaviour with these individuals.

Overview of the thesis results

The five experiments in Chapter Two used a simple action identification task in which different actors were seen acting towards or away from different objects. Unbeknownst to participants, the frequency of each actor's behaviour towards the objects varied, such that one actor would typically interact with one object (e.g., they would kick a ball) and turn away from the other (a computer), and vice versa for the other actor. The results revealed a response time advantage towards more frequent actions in a given situation for each actor, suggesting that participants predicted the actors' typical actions with the objects. These effects of an actor's typical behaviour on identification were elicited even though neither actor identity nor the situation were task-relevant. The results therefore suggest a routine or automatic activation of person-specific action knowledge during action identification, which specifies how the given individuals interact with different objects, and which biases action identification, in a predictive manner, towards these actions.

Importantly, this effect did not seem to be mediated by explicit knowledge. The vast majority of participants did not spontaneously detect the experimental manipulations. They could only verbalise the individuals' different action likelihoods when the questions were re-situated by providing the same cues as the original scenario (person and situation), allowing them to re-activate the relevant internal person models. In this case, participants attributed actor liking of the objects more when the actor tended to act towards than away from them, and could accurately say which object was interacted with more frequently by each actor. Thus, they could explicitly amalgamate the information retrospectively when given the relevant cues, but could not spontaneously provide this information explicitly. Even then, however, the response time effects were present even in those not able to explicitly report the individuals' behaviour, which suggests at least a partial dissociation between this implicit and explicit knowledge (Experiments 1a to e).

Other findings further supported the idea that these results do not merely reflect explicit detection of the experimental manipulation. Strategic responding based on explicit knowledge would predict an effect independent of action type (act towards, turn away), and an effect in both RTs and error rates (e.g., Dale et al, 2012; Duran & Dale, 2009; Marcus et al, 2006). Indeed, evidence for this pattern associated with strategic responding was found when participants were explicitly given the person information (Experiments 1c and d), but not when the information was provided implicitly (Experiments 1a, b and e).

Instead, the findings are consistent with COVIS models (COmpetition between Verbal and Implicit Systems; e.g., Ashby et al., 1998; Maddox & Ashby, 2004) that propose two learning systems, one for verbal categorisation (when the rules can be easily verbalised), and one for implicit categorisation (when the rules are more complex and cannot be easily verbalised). Thus, for the experiment in Chapter Five where the rules for learning are simpler (i.e., Experiment 4 where the situation is constant and only the actor varies), and the explicit studies where the participants are explicitly given the rules (i.e., Experiments 1c, 1d, 1e, 2b), there is evidence of strategic responding (i.e., effects in error rates, and for both actions towards objects and withdrawals) because the learning is primarily in the verbal (i.e., explicit) system. However, in the other experiments where the rules are more complex (both actor and situation vary), the implicit system is employed, and there is no evidence of strategic responding (i.e., Experiments 1a, 1b, 2a).

Experiment 1d showed that implicit prediction effects and explicit strategies could be dissociated within one experiment. When explicit and implicit information were put in conflict, the prediction effect in the response times was still present and reflected how frequently each actor performs each action in each situation (as in the previous experiments). The errors, however, were made based on which actions participants expected to see based on the explicit information. Similarly, when the task did not explicitly provide the person-models, but merely asked for explicit action predictions, participants, again, tend to draw from these person-models (Experiment 2b). Taken together this provides support for the theory that participants can form person-models both implicitly (based on the statistical knowledge of each individuals' action likelihoods) and explicitly (e.g., from gossip). Implicit knowledge primarily affects response times, perhaps through predicting incoming stimuli, but explicitly provided knowledge is actively tested through behavioural wagers, causing participants to make actual errors (see also Dale et al., 2012; Duran & Dale, 2009; Marcus et al., 2006).

A striking finding was that the prediction effects – whether induced explicitly or implicitly – were primarily found for goal-directed actions (actions towards objects but not withdrawals from objects, which have a less clear goal and are not afforded by the objects in the scenes). Thus, not all actions are equal, at least not within this simplistic design. This supports Barresi and Moore's (1996) hypothesis that intentional relations – their version of internal models of other people's behaviour – are primarily formed for goal-directed actions. The findings also link with prior research on a special status for object-related actions that fit the objects' affordances (e.g., Bach et al., 2014). Evidence for this was not just seen behaviourally in response time data, but also in ERPs (Chapter Three). Here, there was evidence that participants saw atypical actions towards objects as an action error on the part of the actor (indicated by early negative activation suggestive of the oERN), but that atypical withdrawal actions did not elicit a similar ERP response. However, in both cases, participants showed evidence of the updating of internal models via a later positivity suggestive of the P3b component.

Finally, while not fully conclusive, the results cannot be easily explained by simple stimulus and/or response learning that would apply similarly to non-social stimuli, rather than internal person-model accounts (see also Chapter Two discussion). First, in Experiment 2a the (o)ERN is typically associated with error processing of own and others actions, indicating that participants represented the stimuli as actions, rather than merely as moving stimuli. Second, in Experiment 2b, verbally associating intentions to the two actors transferred to action identification (see Chapter Three). If participants were just learning simple associations between stimuli and responses, then these verbal intentions should not have affected action identification. Thus, there is evidence across multiple paradigms that participants were creating person-models based on the behavioural tendencies of actors, and reactivating them when the actor was re-encountered in similar situations as opposed to some stimulus-response bias.

Whilst much of the evidence presented in this thesis was based on information acquired during the course of the experiment, Chapter Four tested person-models using older, more naturally-formed information about famous athletes. Participants identified famous athletes with hand and foot button presses that were either compatible or incompatible with the primary effectors in the athletes' sport, while the athletes were either seen performing this action or standing passively, and either in their typical sporty contexts or in neutral situations. The results confirmed, first, the potential embodiment of internal person-models, in the form of contrast effects, such that participants made slower responses when the same effector was needed to identify the athlete as was typically used in their sport. Second, these effects were modulated by how well participants knew the athletes thus providing preliminary evidence that strength of knowledge influences strength of predictions.

Both results replicated prior research that action expectations about others' can be embodied in one's own motor system (Bach & Tipper, 2006; Tipper & Bach, 2011), but the main goal of these experiments was to test whether these embodied prediction effects were modulated by context, and the situation the athletes were seen in, that either afforded their typical effector action or did not (i.e., whether they were seen in the athletes' sporty contexts or neutral situations). Crucially, however, there was no significant influence of context, which suggests that the three factors thought to be pivotal (Chapters Two and Three, see also Barresi & Moore, 1996) may not be equally weighted. Indeed, the evidence (numerically at least) is more in line with Newen's (2015) argument that situation models are only activated during uncertainty (i.e., that when we see an individual, we activate a heuristic for our knowledge of them, which is only 'unpacked' in cases of uncertainty, such as when the athletes are seen outside their usual circumstances).

One of the issues with the experiments in the first three experimental chapters is that the paradigms are quite far removed from reality. It is therefore unclear to what extent the results generalise to more naturalistic settings, and whether predictions guide own motor responses in social interactions (not just action identification). As such, Chapter Five used the Microsoft Kinect Sensor to test these person-models "in action" and using more naturalistic responding. Here, participants had to respond with their feet by moving to the left or right to 'block' a ball, while the players that kicked the ball to them, again, showed different response profiles, with one being biased to kick to the left and the other to the right. Again, the results were suggestive of predictive facilitation towards typical compared to atypical actions for the individual actors, such that participants made their own foot movements more quickly, and in a more pronounced manner, when responding to an expected action of the other player. Thus, this is first evidence that person-models are used when more realistic responses than simple button presses are required, and that they guide own responses in social interactions.

Finally, the role of person-models within more naturalistic settings was also tested in a mimicry paradigm (see Chapter Six), which tested whether participants would mimic a behaviour that they ‘knew’ others would exhibit (based on a prior interaction), but which was not actually shown in this interaction. However, because we could not establish the basic mimicry effect, no accurate measure of such ‘predictive’ mimicry based on internal person-models could be assessed.

Relations to prior research

The findings in this thesis argue against the conventional bottom-up view of social perception whereby incoming sensory stimulation activates conceptual (or motor) representations, allowing the action to be identified (e.g., Iacoboni, 2009b; Rizzolatti & Craighero, 2004; Rizzolatti & Sinigaglia, 2010). Instead, the current findings add to the accumulating literature highlighting top-down involvement in perception, particularly in the social domain (e.g., A. Clark, 2013; Csibra, 2008; Kilner et al., 2007). In such models, the brain constantly uses internal models about the world and other people to form expectations about forthcoming stimuli and tests them against the perceptual input. Expected input can be processed readily (as seen in the response time advantages in Chapters Two and Three, and the earlier and more pronounced actions in Chapter Five), whilst mismatches elicit prediction errors that lead to a revision of the internal person-models (not tested within this thesis).

The current experiments are novel in that they highlight the person-specific nature of such predictive processing. Prior work has shown that other people’s behaviour can act as available cues informing prediction, for example, for emotional expressions (R. B. Adams et al., 2006), action kinematics (Bach et al., 2011; Bach, Nicholson, et al., 2014), gaze (Pierno et al., 2006) and statements of intent (Hudson et al., 2016). Others show that contextual object cues (for a review see Bach et al., 2014) guide action prediction. In contrast, the current studies show that *who* is acting is an important part of making successful predictions. As such, the experiments in this thesis support the idea of a 'Social Prediction System' whereby person-specific internal models are created based on an individual's behavioural tendencies in a given situation, which are then reactivated in a relatively automatic and implicit manner when the individual is re-encountered, and allow one to predict their most likely forthcoming actions.

The results extend the experimental psychology literature that action knowledge about other individuals can be reactivated when they are seen again, such as the body parts used in an athlete's sport, an individual's last seen emotional expression or direction of their gaze (Bach & Tipper, 2006; Frischen, Loach, & Tipper, 2009; Halberstadt et al., 2009; Tipper & Bach, 2011). They add to this by showing that this knowledge aids action identification, by predicting most likely forthcoming behaviour, and can guide own motor responses, and that it reflects not only such static information about other people, but also how they respond dynamically in different situations or towards different objects (see Barresi & Moore, 1996; Newen, 2015).

The findings also directly extend evidence from social psychology that people establish person-models based on behavioural descriptions (Hastie, 1984; Srull et al., 1985; Srull, 1983; Stinson & Ickes, 1992) influencing memory, judgments of others (D. L. Hamilton & Sherman, 1996; Heider et al., 2007; Sherman & D. L. Hamilton, 1994; Stangor & McMillan, 1992; Wyer, 2013), and reading times for (in)consistent behaviours (Belmore, 1987; Dickter & Gyurovski, 2012). Indeed, predictive coding accounts could explain why these so-called prediction errors or inconsistent behaviours generally require longer, more elaborate processing (Graf et al., 2007; Srull & Wyer, 1989). Expected behaviours are processed fluently, whilst inconsistent behaviours elicit prediction errors that need to be resolved. Here, more attention is drawn to the event, which increases processing as the higher hierarchical levels try to explain the discrepancy (Heider et al., 2007). However, while previous studies in social psychology tested relatively abstract processes that happen offline, after verbal descriptions of others' behaviour have been read, the current results reveal similar predictive processes during online action observation, which affect action identification (Chapters Two and Three), the embodiment of the expected actions (Chapter Four), as well as one's own motor output during social interactions (Chapter Five).

Finally, the current results demonstrate how mere behaviour observation can influence abstract knowledge such as perceived liking of an object based on the frequency of interaction with it, as was measured here in post-experiment ratings. Thus, observing an individual provides information not just about their behavioural tendencies, but also provides insights into traits and intentions. This extends research in the social literature that inferences can be made about people based on knowledge of their behaviour or personalities. For example, a common finding is that agent observation typically leads to implicit extraction of the trait: "spontaneous trait inference" (see Chen et al., 2014), or a personality judgment (Vonk, 1994).

The Social Prediction System

The present results can be integrated with the prior literature to develop a model of how social predictions may occur (see Figure 8.1). The “Social Prediction System” follows prior suggestions (Kilner et al., 2007; Csibra, 2008) that social predictions are formed due to an interaction between top-down expectations (based on person-knowledge) and lower-level cues (e.g., what is currently available such as objects and their affordances, eye gaze, facial expressions and body language). When an individual is encountered, prior knowledge – an internal model of how they behave in different circumstances – is reactivated and informs action predictions, which speed up the identification of expected actions (Chapters Two and Three), can be detected in motor activation (Chapter Four), and allows one to anticipatorily plan one’s own action in response (Chapter Five). Although not the focus of this thesis, this person-knowledge need not only be informed by what is directly known about the individual, but can also relate to knowledge of the groups they belong to (sports team, nationality, gender, etc.), and general human ‘schemas’ such as that people get grumpy when they are hungry (e.g., Quadflieg et al., 2011; Quinn & Rosenthal, 2012). It can reflect knowledge that captures the statistical action likelihoods of others as seen in previous encounters (such as in the Experiments 1a, 1b, 1d, 1e, 2a), or explicit knowledge we have about them, either hypotheses about their actions we have developed ourselves or that were given from others (Experiments 1c, 1d, 2b, 3a, 3b, 4).

It is assumed here that this knowledge does not flow directly into action prediction, but is combined with situational knowledge (derived from knowledge of the functions and affordances of objects for example) to provide a best guess for what action is likely in a given situation with a given individual (see also Bach et al., 2014; Barresi & Moore, 1995; Newen, 2015). Objects are represented in human cognition in terms of both the goals that can be achieved with them, and how they must be used for these goals to be achieved (e.g., van Elk et al., 2014). By themselves, objects therefore provide information about someone's most likely actions in a given situation, such as that a hammer predicts hammering, a dish predicts eating, among others (Gergely & Csibra, 2003, Bach et al., 2014). Thus, if one sees a football-sized ball there are limited actions one could do with it; pick it up, throw it, kick it, burst it.

But considering pre-existing knowledge of the individual can further narrow these choices to enable a more rapid, accurate prediction. In other words, the object provides all the possible actions that can occur in the situation, but person-knowledge further selects the most likely action based on prior behaviour, goals, or known (dis)likes. In the above example, therefore, seeing a football would make kicking especially likely if the actor is already known to like football and to frequently engage in this activity. In the present study, such an interaction of person and situation factors was seen in all experiments in Chapters Two and Three (albeit not in Chapter Four), where person-knowledge seemed to act specifically on the actions afforded by the objects, but not when actions are unrelated to the objects.

In such a model, predictions cascade down from higher, more abstract goals, via situational constraints and the available objects, to lower, more concrete goals and actions (see also Kilner et al., 2007; Csibra, 2008). For example, John wants to be a professional footballer, and would therefore be predicted to want to kick the ball respectively. When predictions match reality, no further processing is required, but if predictions mismatch reality it triggers a prediction error and additional processing to resolve the discrepancy. This resolution may come in the form of an altered prediction, or a reassessment of the situation, and may be reflected in longer response times and changes to subsequent person judgments (Chapters Two and Three) and can be detected in the ERP responses, such as the oERN or P3b (Chapter Three).

Via this bottom-up feedback, the Social Prediction System is bidirectional, so information about a given action can also make a ‘best guess’ for person and/or situational knowledge. Assume for example that general person-knowledge is that children prefer sweet over savoury treats. The prediction error of now seeing a child going for a packet of crisps over chocolate could be resolved either on the situation level (it is not a very nice chocolate) or on the person level: this particular child prefers savoury tastes. In the current thesis, this backwards influence may be reflected in the high-level person evaluations seen in the post-experiment ratings that were informed by the behaviour tendencies of the actors (Chapters Two and Three), but of course further studies are needed to further develop this link.

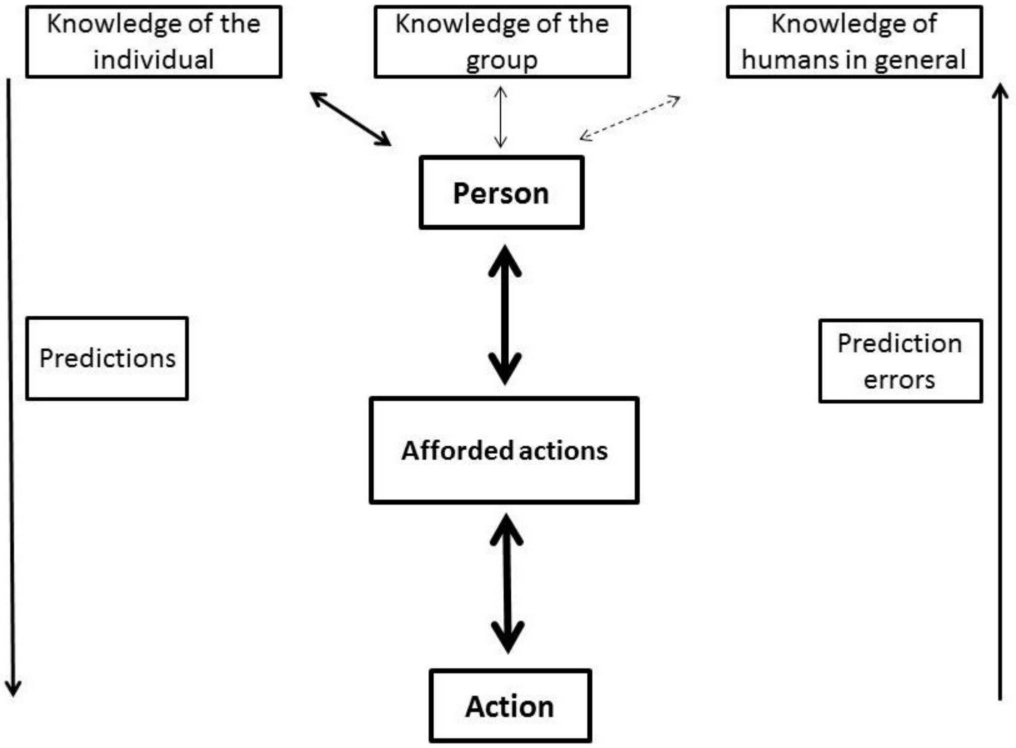

Figure 7.1. The Social Prediction System
Knowledge about the person can either be represented at the individual level, group level or general human level. Knowledge of afforded actions can include factors such as what objects are present, which is heavily linked to what affordances the object(s) warrant to inform what actions are likely to take place. Knowledge about the person and the afforded actions can enable predictions of action, but this process can also work in reverse. When mismatching, prediction errors can trigger revisions about the person or situation models.

Person specificity in action prediction and social interactions

The current model builds directly on the affordance matching hypothesis (Bach, Nicholson, et al., 2014), which theorises that information about intentions and objects informs low-level action predictions. It assumes that objects can provide a wealth of information about a given situation in terms of what functions (goals) can be achieved with a given object, and what actions these functions require (for a review see van Elk, van Schie, & Bekkering, 2014). For example, grasping a cup may afford a precision grip, whereas a tennis ball may require a power grasp (Tucker & Ellis, 1998), while shooting someone requires a gun, which needs to be lifted and triggered. Knowing an actor’s goals, and which objects are available, therefore allows one to derive a ‘best guess’ as to the most likely subsequent action (for a review see Bach, Nicholson, et al., 2014). For example, knowing that someone is thirsty, and seeing them near a glass of water, can trigger the prediction that they will reach for, and drink from, the glass. Indeed, research has shown that even by 12 months of age, infants use their knowledge of object functions to categorise and individuate objects (e.g., Booth & Waxman, 2002; Kingo & Krøjgaard, 2012), Moreover, as seen in the current thesis, afforded interactions with an object are perceived and predicted more readily than non-afforded actions, especially when a higher-level action goal is implied (Bach et al., 2005; van Elk et al., 2009; for a review of further findings, see Bach et al., 2014).

So far, however, the affordance-matching hypothesis does not say much about the person-specific information crucial for making higher level social predictions, and distinguishing between the behaviour of multiple actors. The Social Prediction System, on the other hand, with the assumption of person-specific internal models for behaviour prediction, highlights the importance of who is acting. Thus, it describes the operation of the affordance-matching hypothesis in the context of social interactions to incorporate these higher level, person-specific social predictions. Including such person-specificity is important because, in the same way that an object gives information on how it must be handled and what its purpose is, a person can also act as an affordance by providing various facets of how they act in different situations (Wolpert, Doya, & Kawato, 2003). Various factors can influence these assumptions. Humans can be considered in terms of their attitudes (e.g., John likes football), their beliefs (e.g., theory of mind, the football is in the cupboard), and their behavioural tendencies, as tested in the current thesis.

The affordance-matching hypothesis suggests that if you see a football-sized ball there are limited actions you could do with it; pick it up, throw it, kick it, burst it. Taking into account pre-existing knowledge of the individual can further narrow these choices to enable a more rapid, accurate prediction. So, as the affordance-matching hypothesis suggests, the object provides all the possible actions that can occur in the situation, but person-knowledge further selects the most likely action based on prior behaviour, or known (dis)likes. This is supported by the experiments in this thesis. Even though not task-relevant, how frequently each actor acted towards or away from an object influenced the speed with which participants could identify an action and, in some cases, the amount of errors they made in this action identification task. This was shown both for new person-knowledge learned within the course of the experiment, and for pre-existing knowledge held by participants.

As discussed above, so far, the action prediction literature has rarely considered person-related action information. Next to experiments in the thesis, only a few studies so far provide evidence of person-knowledge informing action predictions. For example, seeing famous tennis players or footballers can inhibit observer use of their hands or feet respectively (Bach & Tipper, 2006; Tipper & Bach, 2011; see also Chapter Four).

In a recent study, we have provided evidence for the interaction of object and person information. Here, we showed that participants' own gaze behaviour reflected the expected gaze of other individuals, based on prior knowledge about which objects these individuals typically like and smile at (Joyce, Schenke, & Bach, 2015), but further experiments specifying this interaction are required.

The importance of person-specific action knowledge is, however, consistent with the social psychology literature. It has already been mentioned that people establish person-models based on behavioural descriptions (Hastie, 1984; Srull et al., 1985; Srull, 1983;

Stinson & Ickes, 1992) influencing memory, judgments of others (D. L. Hamilton & Sherman, 1996; Heider et al., 2007; Sherman & D. L. Hamilton, 1994; Stangor & McMillan, 1992; Wyer, 2013), and reading times for (in)consistent behaviours (Belmore, 1987; Dickter & Gyurovski, 2012). Similar research comes from the study of stereotypes (Macrae & Bodenhausen, 2000), which can be used to establish behavioural tendencies when specific knowledge of the individual is lacking. Indeed, behaviour information is processed faster, and remembered better, when it is congruent to a stereotype or a trait (C. E. Cohen, 1981; D. L. Hamilton & Sherman, 1996; Heider et al., 2007; Macrae & Bodenhausen, 2000; Quadflieg et al., 2011; Srull & Wyer, 1989; Stangor & McMillan, 1992).

In much the same way as we can better discriminate between objects and/or actions when we have specific knowledge or experience with them (Beilock, 2008), knowing more about the person can also aid processing. Once the individual is better-known, more specific knowledge of them can be reactivated based on this prior experience with the individual so there is less reliance on stereotyping and other group knowledge. The difference between such individuated and stereotype use in person-knowledge is supported by evidence that, whilst both famous and unfamiliar faces are categorised by gender initially, famous faces are rapidly (implicitly) re-categorised by identity (Quinn, Mason, & Macrae, 2009a). Similarly, unfamiliar faces are categorised to the most salient visual element (e.g., gender), whereas this is not the case for famous faces (Quinn, Mason, & Macrae, 2009b). Here, Chapter Four provides evidence that embodied prediction effects are seen more when participants were more familiar with the athletes (see also Tipper & Bach, 2011), but further studies are needed to explicitly test when predictions in action observation are made on the basis of stereotypes or individuated person-knowledge.

Whilst much prior research (as described above) has highlighted the importance of person-knowledge and afforded actions separately, few have shown their joint importance (as theorised by Barresi & Moore, 1996). One such study by Macrae, Bodenhausen, and Milne (1995) showed a Chinese woman either eating with chopsticks or applying makeup. Participants more readily attributed her as being Chinese if she was seen with chopsticks, and as being a woman when she was seen applying makeup. Thus, the object she was acting upon influenced the participants’ perception of her.

Even mimicry research (long considered a simple motor-matching process) demonstrates how we use aspects of the person within social interactions. For example, by demonstrating that we automatically imitate bodily movements (e.g., Brass et al., 2000; Chartrand & Bargh, 1999), aspects of our language (see Lakin et al., 2003), gaze behaviour (Frischen et al., 2007) and even pain responses (Morrison et al., 2007) within social interactions, this literature highlights how we change our behaviour to fit our specific interaction partner. Importantly, this mimicry behaviour now appears to be strongly influenced by top-down factors, based on knowledge of our interaction partner. For example, research has shown increased mimicry towards those in power (Cheng & Chartrand, 2003; Dalton et al., 2010), or those in our group (Bourgeois & Hess, 2008). Thus, we attune our actions to emulate those we feel close to, or those we aspire to be like, based on specific aspects of person-knowledge (e.g., the group they belong to, or the attributes they have). This highlights the importance of *who* the interaction partner is, again, providing support for the person-specific nature of the Social Prediction System. Future studies need to establish whether person-models guide mimicry not only through whether someone is imitated, but whether they also determine the content of mimicry, as the experiment in Chapter Six attempted to demonstrate.

Open questions for future research

This thesis investigated the interplay between top-down and bottom-up processes as hypothesised by existing predictive coding models of action observation (Kilner, et al., 2007; Csibra, 2008; Bach et al., 2014). The results provide evidence for a Social Prediction System, which creates person-models based on prior behavioural tendencies of specific individuals in given situations that are reactivated when the individual is re-encountered, and allow the observer to make predictions about their future behaviour. However, as this is one of the first explorations into the person-specific nature of action predictions, several important questions remain open.

Are predictions really being made?

A key question is whether the experiments really demonstrate that predictions are being made. One possibility is that the results may simply reflect stimulus and/or response learning or strategic response preparation, but, as detailed previously, the various experiments in this thesis provide substantial evidence against this notion. Nevertheless, much like the majority of the behavioural action prediction literature to date, the experiments in this thesis largely provide indirect evidence for ‘assumed’ prediction, by demonstrating faster response times and/or lower errors rates for what would be predicted rather than what would not be predicted. The response time effects could therefore reflect faster processing of an individual’s typical actions, and therefore be indicative of person-models, but might not reflect predictions per se.

This problem seems to be present in the broader action observation literature as well. To my knowledge, there is little direct measurement of actual online prediction within the behavioural paradigms of the action prediction literature. For example, eye movement studies show that the observer’s gaze jumps ahead towards the endpoint of an action

(Flanagan & Johansson, 2003), such as the implied target object, but this might simply reflect knowledge of the action goal and subsequent disengagement from the action kinematics, rather than a prediction of the action. Similarly, the action embodiment literature suggests that observers sometimes show motor activation that mirrors an expected but not yet perceived action. The question is, however, whether this motor activation really reflects prediction made for the other person, or just epiphenomenal motor outflow that happens because the observer has identified the other's goal (e.g., Csibra, 2008). In contrast, while the social literature, indeed, tends to measure 'expectations' about others' behaviour, these tend to be tested in a more offline fashion, by abstract judgments of reading times, person judgments, or memory for behaviours (D. L. Hamilton & Sherman, 1996; Heider et al., 2007; Sherman & D. L. Hamilton, 1994; Stangor & McMillan, 1992; Wyer, 2013; Belmore, 1987; Dickter & Gyurovski, 2012), and therefore say little about predictions during action observation.

Experiment 1e provides an initial test of online action prediction, showing that participants can, indeed, predict to some extent what the two actors will do, and in Experiments 1a and 1b, participants sometimes made anticipatory responses towards the expected stimuli. However, future research needs to extend this across paradigms, and in more depth, preferably with further direct measures. There needs to a stronger amalgamation of the paradigms from the person-memory and action prediction literatures. Person-memory paradigms need to be brought more 'online', and action prediction behavioural experiments need to consider more direct measurements rather than relying on mere response time and error data.

One possibility to show such predictions directly is to measure perceptual processes during action observation, instead of the more indirectly related motoric or gaze processes. Some interesting evidence has recently been provided. Kessler, Gordon, Cessford & Lages (2010) showed that biological human motion that can be seen as goal-directed leads to a larger forward bias in perceptual measures than abstract motions for which such a goal is not evident, providing direct evidence of predictive perceptual processing. Similarly, Hudson and colleagues (Hudson et al., 2015; Hudson et al., 2016) have shown in various experiments that implying specific goals of others biases perceptual reports of where an action disappeared, such that participants judged the disappearance point closer to an object when assuming the goal to reach, and further away when assuming a withdrawal. They therefore show that perception is affected predictively, towards the implied goals. Combining such measures with the current person-knowledge manipulations may provide evidence that high level person-models, indeed, affect even low-level perception in a predictive manner.

I know what you will do, but is this explicit or implicit?

The majority of the findings in this thesis suggest that the Social Prediction System operates primarily implicitly, but that the person-models can be brought into explicit awareness and be ‘read’ out when participants are effectively probed post-experiment with both situation and person information (see Chapter Two). In contrast, the prediction effects in Chapter Five suggested that the person-models were primarily explicit, as participants spontaneously detected the experimental manipulation. As previously hypothesised, this dissociation can be explained by the complexity of the rules governing the individuals’ behaviours. The simpler rule set used in Chapter Five which only varied on the one “actor” is more verbalisable than the rules in Chapter Two in which an individual’s behaviour could only be predicted by also considering the situation factor, such that they interacted with one object but withdrew from the other (see COVIS models e.g., Ashby et al., 1998; Maddox & Ashby, 2004).

This hypothesis needs to be tested in future research. In a setup such as Chapter Five, where participants have to interact with an avatar, one could vary the relevance of both situation and actor factors and their interaction, for example, by having some participants throwing and some kicking. Based on both the research about COVIS, and the findings in this thesis, I would hypothesise that when the rules become more complex, and less verbalisable, learning should be more implicit. This would be (to my knowledge) the first time the hypotheses of the COVIS models – that verbalisable rules are processed explicitly, and non-verbalisable rules are processed implicitly – have been specifically tested in more naturalistic and social situations.

A further issue is that the current tests may not be stringent enough measures of explicit awareness (see Shanks & Stjohn, 1994 for extended discussion). For example, it may be that during the basic task (in Chapter Two), participants do have the person-models in their explicit awareness, but they ‘forget’ them after the experiment. However, this is unlikely given that they use this knowledge to answer the liking and frequency exit questionnaires. Moreover, a further experiment (not included in this thesis) directly tested explicit awareness during the task by asking, at intervals throughout the action identification task, what patterns participants were currently aware of. At the end of this experiment participants then simply had to recognise the pattern from a list of seven potential patterns. However, the majority of participants still remained oblivious to the patterns even during the simple recognition task.

Finally, it needs to be addressed how explicit and implicit routes to person predictions differ. As noted, predictions based on explicit person information (“gossip”) lead to participants making errors in action identification, which judgments biased towards the expected actions. In contrast, predictions from implicit action likelihoods of the individuals primarily affected response times. It needs to be resolved why both kinds of prediction have such differential effects. One possibility is, for example, that both predictions reflect processes at different levels of the hierarchy. Explicit predictions might reflect high-level information that can be used for own behaviour planning, allowing participants to make explicit behavioural wagers about what will happen (Dale et al., 2012; Duran & Dale, 2009; Marcus et al., 2006). In contrast, the implicit prediction effects may reflect lower level processes, perhaps reflecting a perceptual or motoric pre-activation of the predicted action. Those predictions might not be accessible enough to induce actual behaviour, but nevertheless speed up identification of the expected actions.

Neither here nor there – how influential are objects in the Social Prediction System?

This thesis provides mixed evidence for the influence of context within the Social Prediction System. On the one hand, Chapters Two and Three highlighted the importance of context, where the actions of individuals were predicted relative to the object they were close to, yet, on the other hand, Chapter Four suggested (albeit with limited power) that context was not used to determine predicted actions. Only for unusual contexts was detailed person-knowledge (action information, context) ‘unpacked’ to resolve uncertainty.

Power aside, a key issue for the discrepancy might be the nature of the initial paradigm (Chapters Two and Three). Here, all cues other than the object and actor were removed from the stimuli and so context was more directly linked to the action than in Chapter Four where athletes were shown in various situations (on the football pitch/tennis court, on a beach, etc.). The athletes, in contrast, in participants’ prior experience, were typically experienced almost exclusively acting, and only rarely in unusual contexts.

Participants may therefore never have established differentiated person-models that would allow them to capture their behaviour across situations, other than a stereotypical association with kicking footballs and playing tennis.

Finally, context was, of course, manipulated differently in both experiments. Whereas context, in Chapter Two and Three, reflected the objects that afforded the individuals' actions, in Chapter Four, it reflected the general situation. While these situations – on the tennis court or the football field – are also associated with the two different actions, they were not affordances in the strong sense of the word, in that they would specify the typical actions that would be carried out with them (Tucker and Ellis, 1998; Gibson, 1979). It therefore needs to be tested whether the situation-specific priming effects when the presence or absence of the respective affording objects – tennis ball or footballs – are saliently manipulated in a setup such as that used in Chapter Four. Perhaps motor activation for kicking and typing is only seen when such affording objects are present, but not for other, unrelated objects.

A similar question relates to the prediction effects that were only found for clearly goal-directed action, but not for those that had no clear goal (turn away from an object). Future research could investigate this difference by, for example, testing whether the driving effect of the acting towards actions is eradicated if the actors turned away from one object to face another object (i.e., narrowing the goal for the turning away actions). This could also be achieved by giving a reason for the turn away trials (e.g., accompanying the visual stimuli with verbal stimuli either saying "Yes, I like the ball" or "No, I don't like the ball" for example). Based on the notion of intentional relations (Barresi & Moore, 1996), and the evidence that the majority of mirror neurons only fire for goal-directed behaviours (for a review see Fabbri-Destro & Rizzolatti, 2008), providing such a clear goal for the turning away trials should assimilate them much more with the acting towards trials thus the prediction effect should be present in both sets of trials.

Monkey see, monkey do – what is the influence of the Social Prediction System on the motor system of the observer?

A key finding was that the Social Prediction System does not merely bias action identification, it also creates motor biases. For example, Chapter Four demonstrated how the person-models can become embodied within the observer, influencing response times for same/different effectors (see also Bach & Tipper, 2006; Tipper & Bach, 2011). However, one of the key issues with both the action prediction and person-memory literatures is that they are often quite far removed from reality. Thus, it is important to further establish the effects of these prediction biases in more ‘real-world’ settings where there are (at least perceived) consequences for the observer.

As seen in Chapter Five, the introduction of the Microsoft Kinect Sensor has wide scope to bring these paradigms into more naturalistic settings or, at the very least, allow more naturalistic responding. This is particularly relevant for measuring embodiment and mimicry. For example, often research has looked at rudimentary embodiment effects such as whether a hand or foot response is facilitated (Chapter Four, Bach & Tipper, 2006; Tipper & Bach, 2011), but it may be that embodiment effects are actually not just effector-specific, but action-specific. That is, it may not be simply the foot that is primed in general, but specifically the kicking action when presented with a famous football player. Thus, the contrast effects seen in Chapter Four may actually be reversed towards the expected facilitation effects if participants had to identify the footballers using a kick rather than pressing down on a foot pedal.

In relation to mimicry research, the major issue of subjectivity within the coding could be resolved by using an automated system such as the Kinect gesture database programmed to identify the gestures of interest. This would not only provide more objective coding, but also coding in a much more time-effective manner. Other more complex investigations could then be carried out such as identifying the response times within mimicry (i.e., the time lag between observing a behaviour and mimicking that behaviour). Similarly, investigations could more accurately assess postural mimicry using the skeletal data from the sensor. This could provide very rich information, and add a lot of new knowledge to the mimicry literature.

To what extent do the results generalise?

Another key avenue for future research is the generalisability of the current findings. The current thesis tested relatively simplistic stimuli as an initial exploration into these person-models. Now that robust evidence demonstrates the importance of person-knowledge for creating and using predictions in action observation, further research can investigate more complex stimuli and situations. For example, future research can investigate how these predictions change during cooperative and competitive situations, or when multiple simultaneous action predictions must be made. It is possible that cooperative situations may require more step-by-step predictions with constant monitoring of the interaction partner required, and constant adjustments to one’s own behaviour. In contrast, competitive situations may require a more goal-directed focus on the observed actions – predictions may be made more holistically about what is needed to ‘win’ in the situation, rather than focusing on the small behavioural changes being made by the interaction partner.

Another key area for investigating the generalisability of the Social Prediction System is to test how much the person-models generalise from one situation to another. For example, if one learns that John likes football (or tends to kick a ball), would this translate into also viewing him as being more sporty in general (or easier to identify in a sporting situation) than George who likes computer games? Furthermore, would this lead to viewing John as being healthier than George, for example? Such effects would allow a more direct test of to what extent uniquely social mechanisms underlie these prediction effects. For example, after participants are exposed to two individuals either acting in sporty or academic situations, one could test to what extent the acquired knowledge is action-based such that any predictive speed up transfers to an equivalent action that achieves the same goal (e.g., making notes on a computer or on a notepad) or reflects attribution of higher level personality traits that generalises even to new situations (i.e., different sporty or academic situations). Such studies would open up the possibility of more closely linking research in social and experimental psychology to provide a common predictive person-model framework for human social interactions.

You’ve got my attention – do person-models influence our attention?

Whilst the current research focused on perceptual aspects of using knowledge to aid action predictions, its influence on attention is another important area of exploration particularly for the phenomenon of joint attention, which is crucial for a range of social behaviours including language acquisition, social development, and fluent social interactions. Based on the current findings it would be hypothesised that, in a similar vein to the perceptual system, predictions may act as primes or markers for attention to enable predictions of where interaction partners will direct their attention based on where they have previously directed their attention, or on prior knowledge such as their (dis)likes. For example, walking on Dartmoor with the knowledge that an interaction partner likes horses would direct attention to the Dartmoor ponies compared to when walking with a keen landscape photographer whose attention would more likely be drawn to the sunset in the distance. This attentional bias would afford the opportunity to assimilate with the individual based on their known interests. Indeed, we have previously found preliminary evidence that knowledge of behavioural tendencies can influence attention in this way within a gaze cueing paradigm (Joyce et al., 2015). Future research can now explore this in different paradigms and using more complex stimuli.

Conclusion

A key aspect of navigating the social world is being able to understand and interpret the intentions and actions of others. One mechanism that may aid this process is the proposed Social Prediction System, which uses person-specific prior knowledge to predict the actions of other people. This knowledge is accumulated over time as the behavioural tendencies of the individual are learned (or as others provide us with information about the individual). This knowledge results in the formation of person-specific internal models, and is re-activated when the same person is re-encountered in a given situation to provide a prediction for how they will behave. When predictions are correct there is little further processing, but prediction errors result in reassessment of the situation or prediction. This person-knowledge takes the form of a person-heuristic, which is rapidly created when we meet an individual. This heuristic is only unloaded if events do not unfold as predicted, and more information is needed to explain the difference between prediction and reality.

Whilst much research into action predictions have focused on the use of bottom-up processes such as the use of available cues, the research field is moving forward with recent models now beginning to explore the top-down processes that also influence these predictions. The current research has provided some key foundations for the influence of such processes, and the basis for a detailed model of how such processing may occur, which fits with much research evidence across multiple fields of investigation. Future research should address the generalisability and boundary conditions of the Social Prediction System, and build on the work of Experiment 1d to explore the exact interplay between top-down and bottom-up processes.

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Appendix

The peer-reviewed journal article containing Experiments 1a, b and d from Chapter Two:

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RESEARCH ARTICLE

The Things You Do: Internal Models of Others' Expected Behaviour Guide Action Observation

Kimberley C. Schenke*, **Natalie A. Wyer**, **Patric Bach**

School of Psychology, Plymouth University, Drake Circus, Plymouth, Devon, United Kingdom

* kimberley.schenke@plymouth.ac.uk

Abstract

Predictions allow humans to manage uncertainties within social interactions. Here, we investigate how explicit and implicit person models–how different people behave in different situations–shape these predictions. In a novel action identification task, participants judged whether actors interacted with or withdrew from objects. In two experiments, we manipulated, unbeknownst to participants, the two actors action likelihoods across situations, such that one actor typically interacted with one object and withdrew from the other, while the other actor showed the opposite behaviour. In Experiment 2, participants additionally received explicit information about the two individuals that either matched or mismatched their actual behaviours. The data revealed direct but dissociable effects of both kinds of person information on action identification. Implicit action likelihoods affected response times, speeding up the identification of typical relative to atypical actions, irrespective of the explicit knowledge about the individual's behaviour. Explicit person knowledge, in contrast, affected error rates, causing participants to respond according to expectations instead of observed behaviour, even when they were aware that the explicit information might not be valid. Together, the data show that internal models of others' behaviour are routinely re-activated during action observation. They provide first evidence of a person-specific social anticipation system, which predicts forthcoming actions from both explicit information and an individuals' prior behaviour in a situation. These data link action observation to recent models of predictive coding in the non-social domain where similar dissociations between implicit effects on stimulus identification and explicit behavioural wagers have been reported.

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Introduction

Predictions are central to our ability to succeed within an ever-changing environment. They allow us to respond quickly to expected events, to fill in ambiguous or missing information, and to identify mismatches between beliefs and reality, should one's predictions not come to pass [1–2]. Nowhere are predictions more important than in social interactions, one of the most dynamic situations in everyday life. Predictions help us to coordinate behaviour with others [3], to interpret their actions [4–6] and to detect deception [7]. Indeed, some of the social deficits of autism or schizophrenia may originate from deficits in predicting own and others' behaviour [8–9].

Prior work has focused on how people derive predictions from social cues and signals, such as emotional expressions [10–11], action kinematics and their match to available tools and goal objects [12–15, 5], object-directed gaze [16], and explicit action goals of others [17–18]. Such cues automatically bias action observation towards the expected actions, allowing rapid and accurate recognition, and planning of one's own actions relative to the expected future state rather than the current input [19–20, 3]. However, overt signals are not the only source of predictions. Humans are remarkably adept at recognizing other people, with evidence pointing towards dedicated cognitive and neuronal systems for identifying others and storing knowledge about them (e.g., [21–24]). This knowledge not only contains information about their appearance, race and sex, but also information directly related to their behaviour. It has been argued [25–27], for example, that humans form elaborate internal models about the people they know [28–29], describing which behaviours they typically carry out with different objects (e.g., Peter typically goes for chocolate), as well as the mental states these behaviours imply (Peter likes chocolate). Once established, such internal models could be automatically re-activated whenever these individuals are seen again and predict their most likely actions.

It is well established that similar internal models guide our perception of the non-social environment. For example, humans have internalised typical behaviour of objects, such that displacements upward (against the effect of gravity) appear more salient than displacements downward, unless, of course, the object is known to be self-propelled like a rocket [30–31]. Similarly, in natural scenes attention is automatically guided towards the likely locations of relevant objects [32–33] and when identifying items in rapidly presented sequences, internal models predict the forthcoming items [34–35], even when these sequences follow complex second-order rules of an artificial grammar [36]. Together, these findings provide converging evidence that (non-social) perception is not a simple bottom-up process but constantly guided, in a top-down manner, by internal models that specify the behaviour of the external world. On a neuronal level, these influences can be traced to activation in low-level visual areas, which anticipate the incoming stimulation [37]. Behaviourally they manifest in speeded up response times to predictable events, often despite an inability to verbalise the underlying causal structure (for a critical discussion see [38]).

Here, we ask whether a similar mechanism exists for social perception, which makes the current actor's typical behaviour in the given situation available to guide action observation. Such a mechanism would have to overcome at least two challenges. First, each human act is jointly caused by a number of hidden factors–goals, beliefs, energy and motivation–that observers do not have access to [39]. To an outside observer, others' behaviour can therefore not be described deterministically but stochastically, in terms of tendencies for action. Second, one of the strongest non-hidden influences on others' behaviour is the current context, with others' exhibiting different behaviours in different situations [5, 25, 40–42]. For example, in personality psychology it has been shown that such a situation dependant encoding of traits allows much more robust descriptions of others behaviour than overarching personality traits (i.e., that a child is shy at school but extrovert at home, rather than shy across situations [43]. Person models would need to capture specifically this situation-dependency of human behaviour, encoding the specific intentional behaviour an individual exhibits towards one type of object, but not towards others (e.g., [25]).

Despite these theoretical proposals, there is currently little evidence that action observation recruits such internal person models [28–29]. As noted above, several studies have shown that observers predict others' actions based on various social cues, such as smiles, gaze, or action kinematics [10–18]. Whilst these cues could indeed exert their effects by providing person information, such as others' goals and beliefs, they could just as well be explained on the level of action alone, where certain cues (e.g., a smile) directly predict certain behaviours (approach), without drawing upon person information at all (e.g., [44–45]). In contrast, social psychology has shown that people establish person models from behaviour descriptions [46–49]. Yet, while these internal person models have been shown to affect reading times of subsequent behaviour descriptions [50], as well as one's explicit judgments and memories of these individuals ([51–53], for reviews see [54–57]), their online use during action observation has not been demonstrated. Other studies have shown that people learn others' looking behaviour towards objects, which then guides attention similarly as directly perceived gaze, and that people automatically activate action knowledge about the people they see [58–59]. However, neither of these studies has demonstrated any predictive impacts on action identification, and the knowledge tested has been very stereotypical, such as the typical behaviours of black and white people [60], the body parts used in sports associated with famous athletes [61–62], or people's emotional expression when last seen [63]. They therefore fall short of the crucial situation-dependency, which is the hallmark of human action [5, 25, 43].

Here, we develop an experimental paradigm in which such person based predictions can be studied. The studies presented here provide a first test of whether (1) once established, internal models of others behaviour are activated when these individuals are seen again, whether (2) these person models exert a predictive influence on action observation, speeding up the identification of expected actions relative to unexpected ones, and whether (3) they capture the situation-specificity of human action, predicting the actions that others' typically perform in one situation but not in others. To test these hypotheses, participants were given a simple action identification task, in which they watched the actions of two individuals (John or Claire) in two situations (sitting next to a computer or standing next to a soccer ball). In each situation, they simply reported, with a speeded button press, whether the individual interacted with the object or turned away from it. To induce action expectancies, we either manipulated, unbeknownst to participants, the actual frequencies of the two individuals' behaviours across situations in Experiment 1 (e.g., Claire would be more likely to kick a soccer ball than type on a computer and vice versa for John), or we gave them explicit descriptions ("gossip") of how the two individuals would behave in Experiment 2.

This paradigm captures both the required stochastic rather than deterministic distributions of others' actions, and their dependency on situational context (i.e., it is not the case that one person simply interacts more than the other, but rather that each person has a specific interaction "signature" across objects). It allows us to test whether internal models of the two individual's behaviour are automatically activated when we watch other people and predict their most likely forthcoming action in the given situation. Even though task irrelevant, the identity of the current actor–and the way in which we have previously observed them behaving with the objects–should then directly affect action observation. Actions should be identified more quickly and accurately if they are typically carried out by this individual in the given situation, compared to actions that are overall equally frequent but are typically carried out by someone else. This is exactly what we find in both experiments.

Experiment 1: Predictions Derived from an Individual's Prior Behaviour

Experiment 1 provides an initial test of whether, once established, internal models of other individual's typical behaviour are automatically activated whenever they are seen again and facilitate identification of their most likely forthcoming actions in the given situation.

Participants performed a simple action identification task, in which they reported, with speeded button presses, whether an actor interacted with or turned away from an object, while both the situational context (in front of a computer or a soccer ball) and the identity of the actor (Claire, John) varied. Unbeknownst to the participants, the two actors had different behaviour profiles such that they were differentially likely to interact with each object (e.g., Claire would be more likely to interact with a soccer ball than with a computer and vice versa for John) whilst the overall action frequency was controlled. If observers establish internal models of the two actors' typical interaction signatures across situations and activate them whenever they are seen again then actor identity should directly affect action observation: actions should be identified more quickly and accurately when carried out by an individual that typically performs this action in the given situation, compared to an individual that carries it out more rarely, even though both actor and object were task irrelevant.

To measure the extent to which such effects depend on explicit knowledge or response strategies of participants, we asked all participants in a funnel debrief whether they noticed any patterns in the stimuli. In addition, we asked them to rate which objects they thought the two individuals "liked" to interact with more. These two questions provide potentially dissociable information [38]. Question 1, whether participants had detected the manipulation, tests for spontaneous awareness of the manipulation during the experiment which participants could have relied on to guide strategic responses. In contrast, the liking question tests for whether any tacit information about the two individuals' behavioural tendencies can be explicitly accessed, in principle, when participants' now-formed person models are appropriately probed. Such responses typically do not reflect explicit knowledge about the global co-variation patterns, but the generation of such knowledge at the time of probing, perhaps by bringing to mind remembered instances of the seen stimuli [38]. In other words, while participants might not have independently detected the contingency patterns during the experiment (Question 1), they might be able to make accurate judgments by "reading out" the acquired internal models retrospectively (Question 2).

We tested these hypotheses in a first group of participants (Experiment 1a) and then replicated in a second, near-identical study (Experiment 1b), which only differed in whether participants were asked to rate, as in Experiment 1a, which object they perceived the two individuals to like more (subgroup 1 of Experiment 1b), or whether they were asked to rate which object they did, in fact, interact with more (subgroup 2 of Experiment 1b).

Method

Participants

Forty-two undergraduates from Plymouth University (31 females, 37 right-handed, mean age = 20.40 years, SD = 3.71 years) took part in Experiment 1a and fifty-seven in Experiment 1b (49 females, 51 right-handed, mean age = 20.39, SD = 5.56 years), in exchange for course credit. In both experiments, participants were excluded from response time and error rate analysis if they detected the experimental manipulation (Exp. 1a, n = 3, Exp. 1b, n = 2), or if they made more than 10% errors (Exp. 1a, n = 2). Sample sizes were determined with G-Power [64] on pilot data from different participants (*n* = 42), which indicated that a sample size of at least 36 was required to reliably detect a main effect of Expectancy (dz = .625) with .95 power. All experiments were approved by the Faculty of Health and Human Sciences Research Ethics Committee prior to data collection, and we report all measures, manipulations and exclusions for all experiments. All participants provided written consent.

Materials and apparatus

The autism quotient scale (AQ; [65]) contained 50 questions to measure the presence of autism-like traits in neurotypical individuals. No relationships were found between autism-like traits and any of the effects in the experiments and will not be discussed further.

The experiment proper was controlled by Presentation (Neurobehavioral systems, Inc; version 14.9, Build 07.19.11) using a Windows XP SP3 1280x1024 32 bit colour 17" display. The stimulus set consisted of 16 different two frame sequences. Each sequence consisted of a neutral image, which showed one of the two actors (John, Claire) in one of the two situations (next to a computer, next to a soccer ball), displayed for 500ms. This image was identical for both actions that might follow (interact, turn away) and served as a prime for the identity of the individual. The second image then showed the actor either interacting with this object (typing on the computer, kicking the soccer ball) or turning away from it. The two images were presented without an inter-stimulus interval, creating the impression of apparent motion [66]. Static images rather than video clips were used to remove, via photo-editing, all cues for context so that only the object and actor were influential. This also provided unambiguous onset times for the action judgments (the second image in the sequence). To control for Simon-like [67] response effects, in one half of the trials, the object was to the left of the individuals, and in the other half on the right (see Fig 1 for an example of the stimuli).

In the first exit questionnaire, participants in Experiment 1a and one half of participants in Experiment 1b rated how much each actor liked each object on a scale from -4 to 4 with no zero point e.g., "How much do you think John liked the ball?". The second half of participants in Experiment 1b rated how much each actor interacted with each object using the same scale (-4 to +4 with no zero point). The second exit questionnaire was a funnel debrief consisting of five questions identifying any explicit knowledge of the experimental manipulation that could guide strategic responses. They were first asked "How easy did you find the task of identifying whether the actors interacted or turned away from the object?" and answered this by circling a

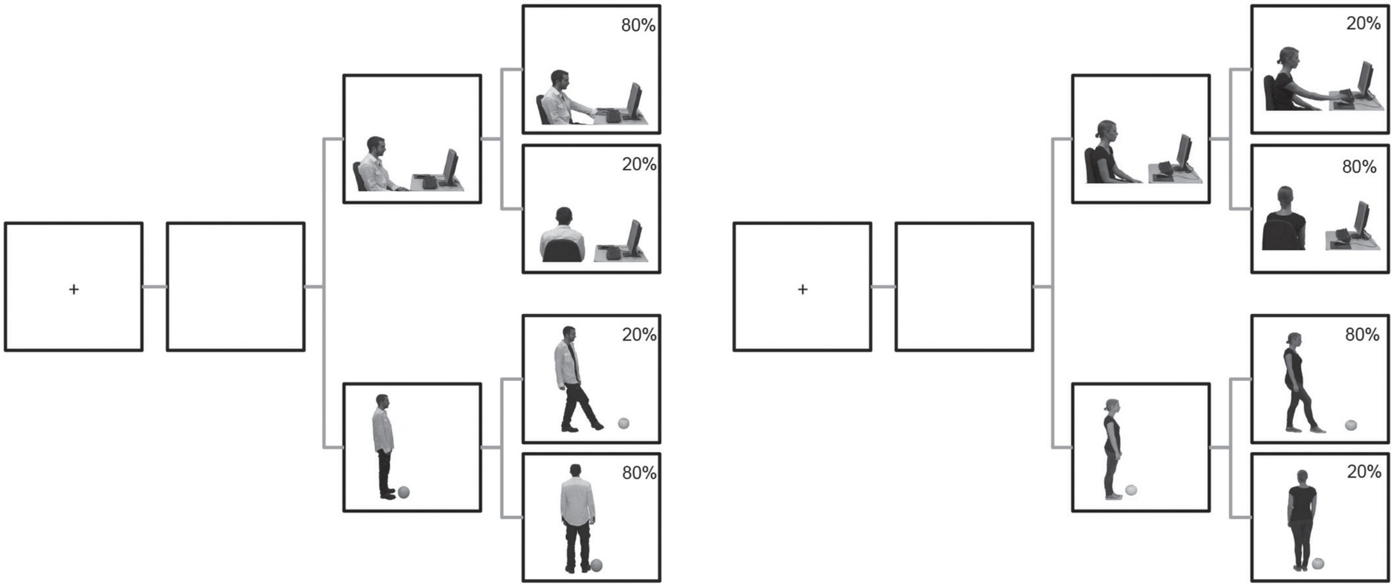

Fig 1. Trial sequence. Each trial started with a fixation cross (400 ms.) and a brief blank screen. Each action started with an image showing one of the two individuals (John, left; Claire, right) in one of the two situations (at a computer, top; near a soccer ball, bottom). They then either interacted with the object or turned away from it, with one individual typically interacting with one object and turning away from the other, and vice versa for the other individual.

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number between 1 "really difficult" and 10 "really easy". They were then asked: "Did you find one actor easier to identify than the other? If so please state which one.", "Did you find one action easier to identify than the other? If so please state which one.", "Did you notice anything unusual about any of the actors or objects?", and "Did you notice any patterns in the stimuli?"

Procedure

Participants completed the AQ and then received written and verbal instructions. When the experimenter was satisfied that the task was understood, participants completed the computer task, which contained 240 trials. Both actors (John, Claire) were shown equally often in each of the situations (computer, soccer ball), but we varied how often they performed the two possible actions in these situations (interacting, turning away). In 80% of the trials, the actors would perform their typical action while in the remaining 20% they would perform the atypical action. Thus, for one participant, John would interact with the computer in 80% of the cases and turn away from it in 20%, while he would turn away from the soccer ball in 80% of cases and interact with it in 20%. Claire would show the reverse contingences (interact with the soccer ball in 80% and the computer in 20% of cases). These contingency mappings were counterbalanced across participants. The trials were presented in blocks of 40 (four repetitions of the eight regular trials and one set of the oddball trials) to ensure an equal distribution of oddballs across the experiment.

Each trial started with a fixation cross in the centre of the screen (400 ms). After a blank screen of 400 to 800 ms (randomly chosen), one of the two frame sequences was presented. In Experiment 1a, the stimulus onset asynchrony (SOAs) between the first and the second frame of the action sequences was either 150 ms or 850 ms. Because no effects depended on SOA, in Experiment 1b, the images followed each other with a fixed SOA of 500 ms. Participants pressed the "UP" arrow key to identify that the actors were interacting with the objects (either typing or kicking) and the "DOWN" arrow key to identify that the actors were turning away from the objects. Participants were asked to respond as quickly and as accurately as possible. If they took longer than 2000ms or responded incorrectly, an error message reminded them of the correct button assignment. After the experiment, participants completed the two exit questionnaires, were thanked and fully debriefed.

Trial exclusions

The same exclusion criteria were used across all experiments. The first twelve trials of each experiment were considered training trials and excluded. Additionally, trials were excluded if they fell within any of the below criteria: 1) trials with RTs greater than 2000ms (maximum duration of the response interval), 2) trials with anticipations (i.e., responses before the critical second frame was displayed), 3) trials where Presentation timing was uncertain (measurement uncertainties larger than 10 ms), and 4) trials with RTs over 3 standard deviations from this participants' condition mean. For the analysis of RTs, error trials were additionally excluded.

Results

4.58% of trials were excluded in Experiment 1a and 1.28% from Experiment 1b (see above for criteria). The remaining data were analysed with a repeated measures ANOVA with the factors Observed Action (act with object, turn away from object) and Action Typicality (typical, oddball), separately for response times (RTs) and error rates.

Response times

The analysis of Experiment 1a revealed no main effect of Observed Action, *F*[1,36] = 2.233, $p = .144$, $\eta\rho^2 = .058$, but a marginally significant main effect of Action Typicality, *F*[1,36] = 3.140, $p = .085$, $\eta\rho^2 = .080$, as well as an interaction between both factors, *F*[1,36] = 6.378, $p = .016$, $\eta\rho^2 = .151$. As can be seen in Fig 2, actions towards objects (kicking a soccer ball, typing on the computer) were identified more quickly when the current actor typically carried out these actions with the objects, compared to when they were atypical for the actor, *t*[36] = 3.330, $p = .002$, Cohen's $d = .16$. However, no such effect was found for withdrawals, *t*[36] = .518, $p = .607$, $d = .04$.

The analysis of Experiment 1b fully replicated these findings. It revealed a marginally significant main effect of Observed Action, *F*[1,51] = 3.070, $p = .086$, $\eta\rho^2 = .057$ and the predicted effect of Action Typicality, *F*[1,51] = 12.314, $p = .001$, $\eta\rho^2 = .194$. Importantly, as in Experiment 1a, this effect was qualified by an interaction of both factors, *F*[1,51] = 12.773, $p = .001$, $\eta\rho^2 = .200$. The RT advantage for typical relative to atypical actions was only present when the individuals acted with the objects (kicking a soccer ball, typing at a computer), *t*[51] = 4.620, $p < .001$, $d = .29$, but not when they withdrew from them, *t*[51] = .379, $p = .707$, $d = .021$. Entering Group (liking questions, frequency questions) into the ANOVA did not reveal any further effects, all $F < 1$.

Error rates

No effects were found in either Experiment (*F*s < 2.124) for the error data, with the exception of a main effect of Observed Action in Experiment 1b, *F*[1, 49] = 5.155, $p = .028$, $\eta\rho^2 = .095$, with more errors for actions towards objects then withdrawals, which was unrelated to our hypotheses.

Anticipations

An important question is whether internal person models only affect action identification times, or whether it also causes overt response anticipations, such that participants identify the expected action even though it is not yet presented (i.e., while the neutral image is still on the screen). Due to the low number of anticipations (6.46% in both experiments), we combined the data for Experiments 1a and 1b to increase power and performed a repeated measures ANOVA with the factors Expected Action (act with object, turn away from object) and Response (typical action identified, atypical action identified) on the data from the participants who made at least one anticipation, $n = 31$. There was a marginally significant main effect of Response, *F*[1,30] = 3.214, $p = .083$, $\eta\rho^2 = .097$, revealing that responses typically anticipate the expected action, but no main effect of Expected Action ($F = 2.161$), nor an interaction between the two ($F = .171$). Thus, the anticipations show that others' typical behaviour does not only affect action identification, but also sometimes causes participants to anticipate the forthcoming response while the neutral image was still on the screen.

Liking and frequency ratings

After completing the action identification task, participants rated how much the two individuals liked the two objects (in Experiment 1a, and subgroup 1 of Experiment 1b), and how much each individual had interacted with them (subgroup 2 of Experiment 1b). In Experiment 1a, objects that were typically acted upon by the given individual were rated as more liked by this individual ($M = 1.79$, $SD = 1.52$) than objects this individual typically turned away from ($M = -0.17$, $SD = 1.89$), *t*[36] = 3.818, $p = .001$, $d = 1.05$. This effect was replicated in Experiment 1b. When the objects were typically acted upon they were rated as more liked ($M = 1.74$,

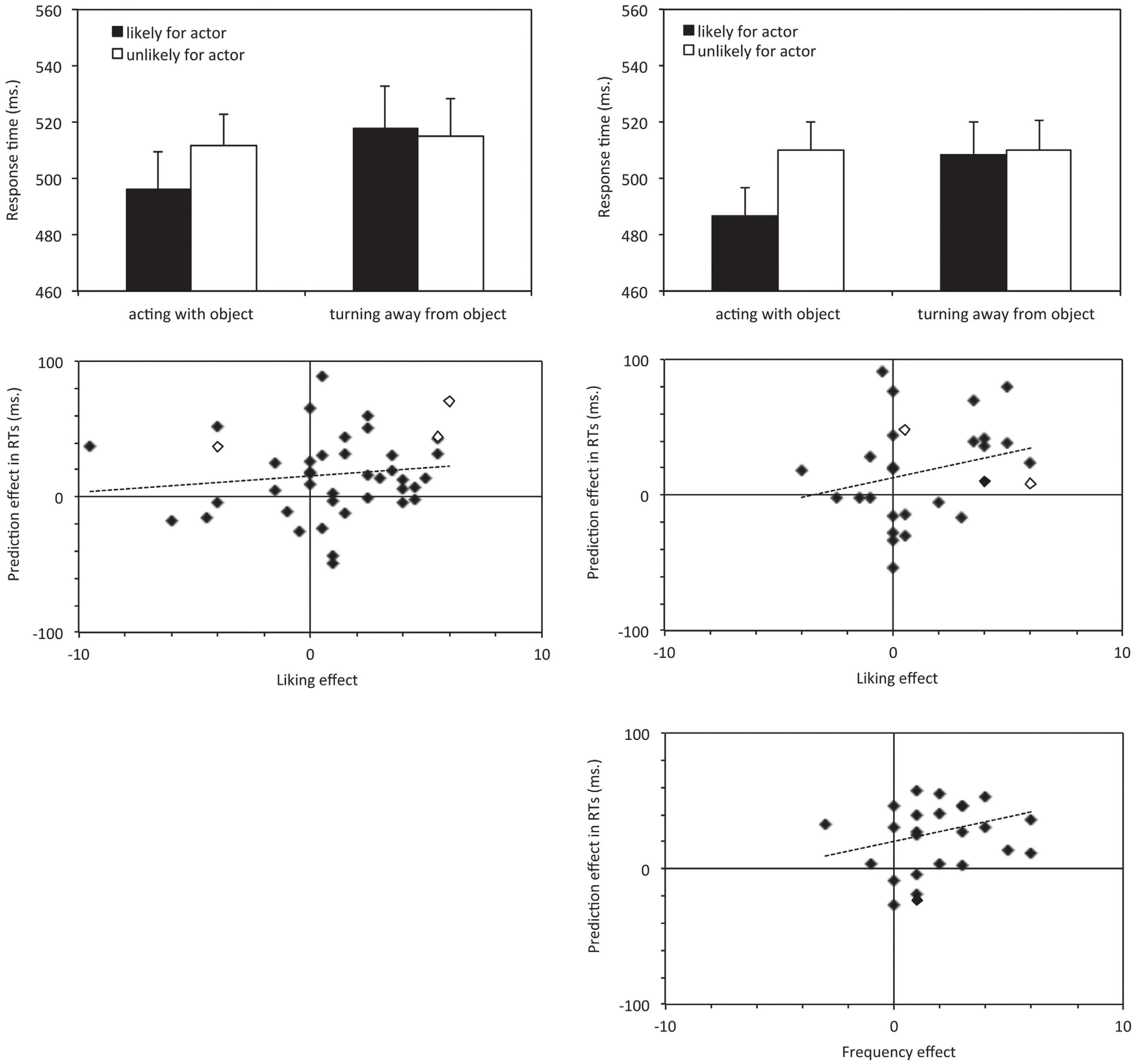

Fig 2. Experiments 1a and 1b RT and liking results. Top panel: average response times in Experiment 1a (left panels) and 1b (right panels). In each panel, the left bars show identification of actions towards objects (typing on a computer or kicking the soccer ball) and the right bar shows withdrawals from these objects. The black bars reflect actions expected of this individual in the given situation, and white bars show the action expected of the other individual. Error bars show the standard error of the mean. Middle and bottom panels: correlation between prediction effects in the RTs for actions towards objects and the corresponding differences in perceived object liking and interaction frequency, for individuals who either identified (unfilled diamonds) or did not identify (filled diamonds) the behavioural pattern.

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SD = 1.21) than when they were turned away from (*M* = 0.40, *SD* = 1.82), *t*[26] = 2.498, *p* = .019, *d* = .80. Similarly, when the objects were typically acted upon they were rated as being interacted with more (*M* = 2.20, *SD* = 1.06) than when they were turned away from (*M* = 0.50, *SD* = 1.49), *t*[24] = 4.332, $p < .001$, *d* = 1.30, Having established that participants can access some explicit information about the two individual's behaviour, we then tested whether explicit person knowledge predicts the effects during action identification. We therefore also included those participants that explicitly detected the contingencies between individuals, objects and actions (but also report if results depend on these participants). A regression analysis measured the relationship between apparent explicit awareness of individuals' behaviours as seen in the liking and frequency ratings, and the response time effect for actions towards objects (difference between likely and unlikely actions for the actor), for each of the three participants groups separately. None of the three participant groups showed a significant correlation, (Exp 1a, $r = .187$, $n = 40$, $p = .248$; Exp 1b liking, $r = .252$, $n = 28$, $p = .195$; Exp 1b, frequency, $r = .210$, $n = 26$, $p = .304$). However, in each, the intercept was different from zero (Exp 1a, $t = 3.325$, $p = .002$; Exp 1b liking, $t = 1.710$, $p = .099$; Exp 1b, frequency, $t = 2.117$, $p = .045$), indicating that even those with no apparent explicit awareness in the liking or frequency ratings still showed significant RT prediction effects. The same pattern is seen when three participants who detected the manipulation were excluded, with the exception that the intercept for the liking ratings in Experiment 1b now failed to reach marginal significance ($t = 1.519$, $p = .142$).

To attain enough power to detect weaker correlation effects, the data from all three subgroups were pooled. These analyses indeed revealed a marginally significant correlation between the post-experiment ratings and the response time effects (all participants, correlation; $r = .186$, $p = .073$; unaware participants only, correlation; $r = .181$, $p = .089$). In addition, they confirmed the significant intercept (all participants, $t = 4.957$, $p < .001$, unaware participants only, $t = 4.544$, $p < .001$), indicating that even those who were unable to explicitly recall the individuals' behaviour still showed reliable response time prediction effects.

Discussion

Experiment 1 tested whether internal models of others' typical behaviour are automatically reactivated whenever they are seen again, and predict their most likely forthcoming actions in the given situation. Indeed, actions were identified more rapidly when they were typical for the given individual in the given situation, compared to an action that is, overall, equally frequent but typically carried out by another individual. These effects of actor identity on action observation were found even though individual and situation were task irrelevant, and the overall frequency of each action was controlled across situations and individuals. As such, they provide first evidence that watching other people goes along with activation of internal person models that describe these individual's typical behaviour in the given situation, which biases identification towards their most likely forthcoming action.

A striking observation was that in both experiments action expectations affected the identification of actions with objects (e.g., kicking the soccer ball, typing on the keyboard), but not withdrawals from them. Although not predicted, this finding is in line with the proposal that action prediction specifically occurs for meaningful actions towards objects, ([for a recent review, see [5]; see also [13–14, 25]), and that object avoidance is coded on a second-level, as an inhibition of a potential approach [68–69]. For example, even though there are neuronal populations for representing intransitive action [70–71], the majority of mirror neurons, one of the proposed core mechanisms of action understanding and prediction, fire only for actions towards objects (for a review see [72] and even in humans object-directed actions are represented in dedicated neuronal populations [73]). Indeed, studies in humans show that afforded interactions with an object are perceived and predicted more readily than non-afforded actions [19, 74] and studies on high level mentalizing abilities show that predictions of what other people will do (e.g., in theory of mind tasks) occur for approach related behaviours but not for avoidance behaviours [68–69]. Our results are therefore in line with these studies and further support the special status of object-directed actions in action observation and prediction.

The effects of actor identity on action identification are unlikely to result from strategic responses of participants that detected the experimental manipulations. Only five participants spontaneously detected the experimental manipulation when probed after the experiment. Moreover, if the effects reflected strategic response preparation they should have been found not only for interactions with objects, but also for withdrawals, especially as overall response times between these conditions did not differ. Yet, faster responses were only found for meaningful actions towards objects, but not actions away from them. Finally, explicit response preparation effects should specifically affect error rates, not only response times [75–76], but no such effects were detected.

Importantly, though, when explicitly probed after the experiment, participants could make reliable judgments about which objects the two individuals liked more and which they tended to interact with. Thus, if John was typically seen interacting with the computer but turning away from the soccer ball, participants were able to retrieve this information when directly prompted, and he was later judged to like computers more than soccer balls. Importantly though, while the data reveal some weak relationships between these post-experiment ratings and prediction effects in response times, they also showed that even those participants that did not show any rating effect still showed significant prediction effects. This finding is in line with the idea that explicit knowledge is not the basis for the prediction effects but that, instead, these internal models of others' behaviour are not fully opaque, but can be accessed to generate behaviour information, perhaps by playing through relevant instances in memory (for similar dissociations, see [77–79]).

Experiment 2: Explicit Knowledge of Others' Behaviour

Action observation is not our only source of information about our interaction partners. People love to gossip (e.g., [80]) and mutual acquaintances are a rich source of information about other people, which might exert similar predictive influences on action observation. This is also the typical situation tested in prior work in social psychology where the influence of explicit person descriptions on subsequent person memory and reading times were tested [81, 51, 53, 56–57]. The current study attempted to capture this explicit social knowledge, and tested whether such explicitly derived person models have similar or different effects on action observation as the actual behaviour pattern of the individuals in Experiment 1, and whether they interact with this (potentially conflicting) information. At the start of the experiment, participants were given an explicit description about the two actors' typical behaviour ("George typically kicks the ball but rarely types on the computer"). They then performed the same action identification task as in Experiment 1. Across blocks within the experiment, the actual behaviour tendencies could either follow the person description (in 75% of the trials the individual acts according to expectations and counters the expectations in the remaining 25% of trials), conflict with the prior description (the individuals' actions counter the expectation in 75% of the trials), or could be equivocal (they carried out the described action in 50% of the trials and the alternative action in the other 50%). To ensure that participants would perceive the individuals' behaviour in light of the prior behaviour descriptions, we asked them to assess, after each block, to what extent individuals' actual behaviour matched the initial description.

This task therefore pits implicitly derived internal models of other people from those derived by explicit information. It allows us to test, first, whether explicit information about others leads to similar biases in identifying their actions as found for implicit statistical manipulation of their behaviour. Second, it allows us to test the extent to which explicit and implicit predictions interact or are independent of one another.

Method

Participants

49 participants (39 females, mean age = 20.92 years, SD = 6.06; 44 right-handed) took part in the study in exchange for course credit. One participant was excluded for making more than 10% errors.

Apparatus & Materials

Stimuli and the course of each trial were identical to the previous experiments. The experiment was controlled with E-Prime 2.0 (Psychology Software Tools, Pittsburgh, PA), and responses were recorded with button boxes.

Design and Procedure

Participants received detailed instructions then underwent 16 explicit practice trials in the action identification task of Experiment 1b (more practice trials were needed here than in the previous experiment due to the increased difficulty highlighted by pilot testing). All actions in the practice trials were carried out by a third actor who did not appear in the main experiment. Participants were then informed that whilst performing this task they would also be asked to perform a second task and assess whether a person description matches the individual's actual behaviour. For practice, they were informed that the actor typically kicked the ball but turned away from the computer. They then underwent 12 further practice action identification trials, in which 8 of the trials supported the hypothesis and 4 contradicted it. They then rated how much they agreed or disagreed that the seen behaviour corresponded to the prior person description on a 4-point scale (1 = "completely disagree", 4 = "completely agree").

After both participant and experimenter was satisfied that the task was understood, the participant was given an explicit description about the actors' typical behaviour (e.g., that John typically kicks the ball but turns away from the computer, or vice versa, and that Claire has the opposite preferences), and that they had to evaluate the appropriateness of this behaviour description after seeing the individuals' actual behaviour in each of the experiments' nine blocks (32 trials each). At the start of each block participants were reminded of the explicit person description and that this was a new set of trials and to ignore what they had seen previously. They then performed the action identification task of Experiment 1b. The individuals' actual behaviour differed in each block, such that it could either conform to the prior person description (75:25), be equivocal (50:50), or contradict it (25:75), such that the actors performed the opposite action more frequently. At the end of each block, participants rated whether they agreed that the individuals' behaviour corresponded to the person descriptions at the start of the experiment. Block order was randomised across participants.

At the end of the experiment, the social intelligence scale [82] was administered. The scale consists of 21 questions each on a 7 point Likert scale. Examples of questions are "I can predict other peoples' behaviour", "I often feel uncertain around new people who I don't know" and "I can often understand what others mean through their expression, body language, etc." There were no significant correlations between this scale and the effects seen and so this will not be discussed further.

Results

Response times

7.26% of trials were excluded in total (5.33% errors and 1.93% for RTs greater than 3 SD from the mean). The remaining data were analysed with a repeated measurements ANOVA with the

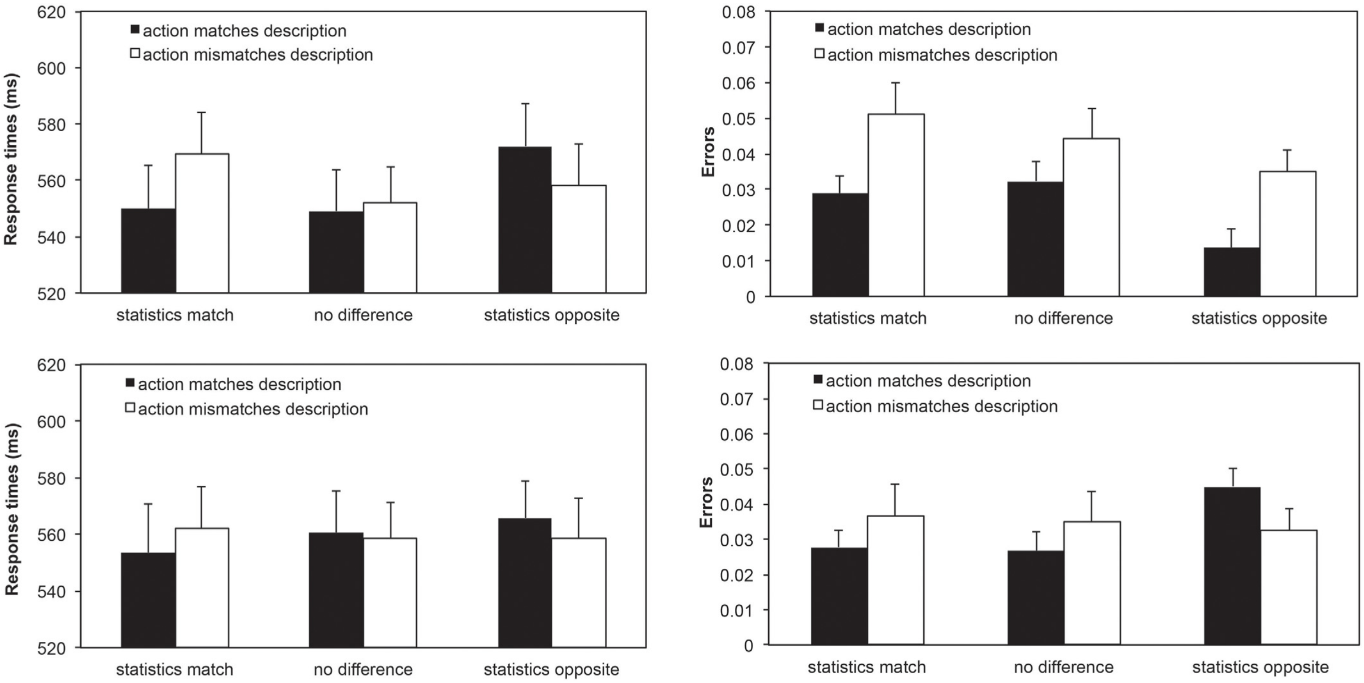

Fig 3. RTs and error rates for Experiment 2. The black bars represent trials which followed the hypothesis and the white bars represent trials, which are the opposite of the hypothesis. The left side shows the response times and the right side shows error rates. The top row indicates actions towards objects and the bottom row indicates withdrawals. Error bars show the standard error of the mean.

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factors Action-Description Match (the observed action follows/does not follow the person description), Block-Description Match (observed statistics in the current block matches the person description, are equivocal, contradict the description), and Action Type (act toward object, withdraw from object).

The analysis of RTs (Fig 3, left panels) revealed no main effect of Block-Description Match, $F[2,44] < 1$, nor of Action-Description Match, $F[1,47] < 1$, nor of Action Type, $F[1,47] < 1$, providing no evidence that actions that matched the explicit information were generally identified more quickly than mismatching actions. Importantly, there was an interaction between Block-Hypothesis Match and Action-Hypothesis Match, $F[2,46] = 5.062$, $p = .010$, $\eta\rho^2 = .180$, signalling that response times were driven by the statistical regularities in a block, but not the explicit person description. In a block in which the individuals' behaviour matched the prior description, participants more quickly identified actions that matched this description ($t = 2.260$, $p = .029$, $d = .66$). However, in blocks where the action likelihoods were equal (and the individuals acted randomly), there was no differences between actions that matched or mismatched the prior person description ($t < 1$). Finally, when the actors' behaviours in a block contradicted the person description, the effect reversed, too, with RTs being faster for trials that mismatched the person description (but therefore matched the statistics in the block), $t = 2.060$, $p = .045$, $d = .60$. These data therefore reveal no effect of prior explicit person information but replicate Experiment 1 and show that internal person models derived from an individual's action likelihoods affect response times even within relatively short blocks of 32 trials. There were no other effects (Fs < 2.391). In Experiment 1, action likelihood specifically affected actions with objects but not withdrawals from them. We therefore tested whether the RT effects are similarly driven by these actions towards objects. Indeed, planned comparisons revealed no significant effects (all

Fs<1.376) for withdrawals, while the acting towards trials showed the relevant interaction between Block and Hypothesis Match, *F*[2,46] = 4.471, *p* = .017, $\eta\rho^2$ = .163.

Error rates

Error rates were analysed with the same ANOVA model as the RTs. It revealed no effect of Block-Description Match, *F*[2,46] = 1.099, *p* = .342, $\eta\rho^2$ = .046, nor of Action Type, *F*[1,47] = .360, *p* = .552, $\eta\rho^2$ = .008, but a main effect of Action-Description Match, *F*[1,47] = 7.404, *p* = .009, $\eta\rho^2$ = .136. Participants made more errors when actions conflicted with the prior person description. This effect was qualified by an interaction of Action-Description Match and Action Type, *F*[1,47] = 6.385, *p* = .015, $\eta\rho^2$ = .120, showing that the increase of errors for non-expected actions was stronger for actions towards objects than withdrawals, as was found in the previous experiments for statistical person information. Indeed, pairwise comparisons showed that the main effect of Action-Description Match was present for actions towards objects, *F*[1,47] = 15.740, $p < .001$, $\eta\rho^2$ = .251), but not for withdrawals ($F < 1.265$). Finally, there was an interaction of Block-Description Match and Action Type, *F*[1,47] = 3.790, *p* = .030, $\eta\rho^2$ = .012 but this was not relevant to our hypotheses.

Behaviour ratings

Data to what extent the individuals were rated to have followed the person description in the different blocks were analysed with a one-way ANOVA with the factor Block-Description Match (blocks either matched the hypothesis, mismatched the hypothesis or showed each action equally). This main effect was significant, *F*[1, 143] = 72.053, $p < .001$, showing that participants reliably distinguished the different behaviour patterns in the three types of blocks. Agreement was higher when the actors' behaviour in a block matched the prior person description (*M* = 2.97, *SD* = .51) than when action likelihoods were equivocal (*M* = 2.27, *SD* = .36), *t*[47] = 8.201, $p < .001$, or opposite to the description (*M* = 1.93, *SD* = .42), *t*[47] = 10.391, $p < .001$. Moreover, they were higher for equivocal likelihoods then distributions opposite to the person description, *t*[47] = 6.096, $p < .001$.

Discussion

Experiment 2 showed that internal models of others' behaviour can be established either from observing their typical behaviour or from explicit person descriptions, with both having dissociable effects on action identification. The two individuals' action likelihoods affected action identification times (but not error rates), such that actions towards objects were identified more quickly when they were typically carried out by this individual in the given situation, compared to actions that were carried out more rarely. In addition to replicating Experiment 1, these findings show that person models can be established from relatively few exposures (32 trials in a block) and exert their influence spontaneously, despite the secondary task of assessing the individual's behaviour.

In contrast, explicit behaviour descriptions about the two individuals directly affected error rates (but not response times), such that an action was more likely to be misidentified for the action that was currently expected (e.g., identifying a kick as a withdrawal when a withdrawal was expected). This effect on error rates is striking given that the participants were aware that across blocks the actions were equally likely to match and mismatch the behaviour description, and that they were instructed to evaluate whether the explicit information was correct or not. Merely maintaining a hypothesis about someone else's behaviour may therefore induce a subtle tendency to act according to this prediction, even when explicitly trying to keep an open mind.

The differential effect of explicit and implicit information is consistent with other research on predictive coding in the non-social domain. Implicit information about statistical regularities often affects response speed, perhaps because it allows relatively low-level perceptual (or motoric) anticipations of forthcoming events [76]. Explicit information, in contrast, provides higher-level assumptions that might induce a tendency to make explicit "wagers" about what will be observed, which allows people to overtly test any hypothesis they have about the regularities guiding the events against reality [83, 75]. Indeed, in a recent study, it was exactly these explicit behavioural wagers that were associated with the explicit (rather than implicit) recognition of the underlying rules that governed the event sequences [76]. As such, the present dissociations are in line with predictive coding work that sees behavioural wagers as key learning mechanisms for explicit learning and verification of explicit hypotheses. In addition, it further confirms that the response time effects do not reflect this currently available (and explicitly tested) person model, but rather statistical information about other's most likely behaviour with the different objects.

General Discussion

In two experiments, we tested whether observers use internal models about other individuals' typical behaviour in different situations to predict their most likely forthcoming actions. In Experiment 1, participants performed a simple action identification task–whether the actor interacted or withdrew from an object–while we manipulated, unbeknownst to them, the probability distribution with which the actors performed these behaviours across situations (i.e., one individual typically interacted with a soccer ball but withdrew from a computer, and vice versa for the other individual). We found that action identification was indeed sensitive to actor identity, being faster for actions that were typical for an individual in a given situation, compared to actions that were overall equally frequent but typically carried out by someone else. This effect was found even for participants that were unable to report the individuals' typical behaviours and even though both situation and person were task irrelevant, suggesting a largely automatic effect.

Experiment 2 then showed that similar–but dissociable–effects are evoked for explicit information about the acting individuals. Here, participants evaluated behaviour descriptions about the actors while we varied, in different blocks, the extent to which the actors indeed followed these patterns. We found that the actor's actual action likelihoods again sped up identification times, showing that these prediction effects adjust to new statistics within very few exposures (32 trials within a block). In contrast, explicit behaviour descriptions affected error rates, causing participants to respond according to the explicit predictions instead of what was perceived. This bias was observed even though participants were asked to merely evaluate the given behaviour descriptions, and were aware that the actual behaviour may differ. Simply evaluating a hypothesis about others' behaviour may therefore induce an involuntary confirmation bias [84] towards these actions irrespective of the actual behaviour patterns, or involuntary behavioural "wagers" where participants test their explicit action hypotheses against reality ([76], see also [83, 75]).

The two experiments provide converging evidence that internal person models influence action observation in a predictive manner, such that the actions others are most likely to carry out are identified faster and more accurately. These findings are in line with recent theoretical work that has re-conceptualised social perception, away from conventional bottom-up mechanisms that match kinematic information to own action knowledge [85–87] towards interactive models, in which action observation is constantly guided by prior knowledge [4–6]. As found here, these models assume that top-down information about the person (action tendencies, goals, beliefs) is constantly integrated with the situational constraints (objects available for goal achievement) to predict the most likely actions. Expected actions should therefore be processed rapidly, while unexpected actions cause salient prediction errors and revisions of one's person models. While previous research has revealed that such expectancies are derived from social cues (e.g., [10, 13–16, 19, 88]), the present data reveal an influence of actor identity and the internal models of their behaviour: what we were told about them and how they have responded in the same situation before.

To our knowledge, this is the first study to show such a top-down effect of person models on online action observation. While it is known that person models provide a reference frame against which others' behaviour can be judged [46–48], prior studies used measures that were far removed from online action observation, such as reading times or memory about individuals [51, 53, 55–57, 81]. Other studies have shown that people re-activate action-related information about others whenever they are seen, but this knowledge has been very general and does not reflect how these individuals behave in different situations (e.g., the body parts used in the sport of famous athletes, [61–62]; prior emotional expression or direction of gaze, [63, 58–59]). Our new data now show, first, that internal person models can affect online action identification, and that, second, this person knowledge is organised around discrete situations, reflecting not only *what* somebody typically does, but also in *which situations* these actions occur [25].

A striking finding was that the effects on online action identification were largely de-coupled from the participants' ability to make explicit judgments about the two individuals' behaviour. In Experiment 1, participants were able to accurately judge how frequently the individuals had interacted with the objects and how much they "liked" these activities. Yet, while these judgments were weakly related to the response time effects, the speed up for expected actions was found even in those who were unable to make such judgments. Similarly, in Experiment 2, while giving participants explicit knowledge about the individuals also led to overt biases in action identification, it did so differently than implicitly acquired person knowledge, affecting error rates instead of response times, causing participants to sometimes respond in line with their expectations rather than observed reality.

Similar dissociations are also known from social psychology. The explicit judgments that people make about others are often abstracted away from the behaviours that were actually observed, leading to a similar lack of strong correlational relationships as observed here [77–78]. It has therefore been argued that participants might not make explicit judgments during social perception at all. Only when explicitly asked after the experiment, they form such impressions in an ad-hoc manner, by relying on their (imperfect) memory of what was previously observed. In such a view, the response time effects in Experiment 1 reflect the automatic generation and activation of person models when these individuals are seen. The post-experiment explicit rating effects, in contrast, reflect attempts to "read out" these models, in a retroactive fashion, perhaps by simulating/imagining the observed events that one has previously observed, and drawing conclusions about them.

This interpretation is also in line with research on causal or statistical learning. People are able to learn even complex second-order relationships between events, and respond faster to expected stimuli, compared to unpredicted ones. In many cases, this knowledge cannot be explicitly verbalised by participants and even if they can, it is not diagnostic of prediction effects in the response time task (e.g., [89–90]; for a critical view, see [38]). As argued above, this does not mean that there are two separate systems for implicit and explicit learning. Instead, it might suggest that participants solve explicit tasks by trying to re-activate their internal models based on the cues provided, but that this re-activation is imperfect and differently effective in different individuals (e.g., [89, 91–92, 38]).

The observed distinction between implicit and explicit knowledge affecting response times and error rates, respectively, is particularly in line with such models. Recent work in predictive coding suggests that implicit information about statistical regularities often affects response speed, because it might support relatively low-level perceptual (or motoric) anticipations of forthcoming events [76]. In contrast, explicit hypotheses about forthcoming events provide higher-level inferences that were constantly tested with explicit behavioural "wagers", which are then either confirmed or disconfirmed through the errors participants make ([76]; see also [75, 83]). Our results therefore suggest that social expectations may be similarly tested against the individual's actual behaviour.

Whilst social research demonstrates the continued influence of initial trait expectancies on categorising behavioural descriptions (e.g., [48. 53, 57]), in Experiment 2 we find that observed actions very quickly adjust the initial hypothesis, such that participants are able to judge the actual behaviours accurately after each block. This may be because the more concrete actions of our research have a stronger "updating" effect, or that the described behaviours ("John will mostly type on the computer, but turn away from the soccer ball.") are more specific than the trait expectancies of the social literature which tend to be much more general and thus more robust against incongruent behaviours (for reviews see [54–57]). However, it could also be that most social studies generally do not investigate effects while impressions are still being formed. Indeed, one study showed that providing atypical group members once a stereotype is formed leads to this information being largely ignored, but if these group members are given whilst the stereotype is being formed it weakens the stereotype [93]. Thus, as it was the case in the current study, person knowledge is malleable by contradictory behaviour while it is still being formed, but less so when fully established.

As this is the first study investigating the activation of internal models of other people, some questions remain unanswered. First, the current study shows that, once established, internal models of other people's behaviour are accessed fluently during action observation and bias the identification of the action towards these predictions. However, the range of situations and actors was by necessity restricted and the stimuli were relatively simplistic. It is therefore important to establish that people can also acquire internal models of others in real life social interactions, where participants meet a larger number of different individuals across a variety of more loosely connected situations that offer a variety of action possibilities that nevertheless suggest similar underlying traits (e.g., sporty and academic situations such as libraries, lecture halls, and fitness studios).

Such studies would also help solve the second question, namely whether the mechanisms underlying these predictions are uniquely social or whether they rely on domain general mechanisms. As noted, humans routinely acquire even complex relationships between stimuli, social and otherwise, and can use them to predict what comes next e.g., reaching from artificial grammar sequences [36]. Several theorists argue that the internal models one builds of other people are very similar, implying a continuity between the learning mechanisms for physical and social causality [94–96]. A question is therefore whether the current results can be accounted for by more general non-social mechanisms as well, which, for example, simply learn the contingencies between subsequent stimuli, whether they are social or non-social.

Although this was not the focus of this first study, several aspects of our research suggest a reliance on at the very least action-specific information. First, our prediction effects were restricted to predictions of object-directed actions, but not withdrawals. While this finding is very much in line with prior findings of a special status of goal directed actions during both action observation and prediction (see above, and [5] for a review), it is hard to account for by abstract stimulus based learning, which should apply to all stimulus types equally. Second, we found that similar prediction effects (again restricted to actions towards objects) were obtained when person information was explicitly given in Experiment 2 in a decidedly social format: which actions the two actors typically carry out with the objects. It is hard to see why participants would have effortfully translated these descriptions into non-social contingences prior to the experiment, especially as they had to evaluate these person descriptions after each block. Finally, while the effect was weak and could only be demonstrated when data was pooled across groups, the response time prediction effects were weakly related to subsequent person ratings: how much the two individuals interacted with and liked the objects. Again, from the viewpoint of mere stimulus learning, such relationships would not be predicted. It suggests that at the very least some of the learning during the response time task is drawn upon when making person judgements, suggesting a social or at least action based encoding of the stimuli.

Future studies will need to more directly test to what extent uniquely social mechanisms underlie these prediction effects. The type of experiment specified above would help solve these questions. For example, after participants are exposed to two individuals either acting in sporty or academic situations, one could test to what extent the acquired knowledge is action based such that any predictive speed up transfers to an equivalent action that achieves the same goal (e.g., making notes on a computer or on a notepad) or reflects attribution of higher level personality traits that generalises even to new situations (i.e., different sporty or academic situations). Such studies would open up the possibility of more closely linking research in social and experimental psychology to provide a common predictive person model framework for human social interactions.

Conclusions

This study reveals that observers routinely access both explicit and implicit knowledge about which actions the observed actor typically carries out in the given situation, which allows them to rapidly identify these expected actions. These data provide evidence for a person-specific social anticipation system, which tracks the actions that others exhibit towards the environment and uses them to predict their forthcoming actions, in a situation-specific manner. Our results support recent models in which action identification emerges from an interaction of bottom-up cues and such top-down expectations derived from prior knowledge about others' behaviour in different situations.

Supporting Information

S1 File. an excel file for the raw data.
(XLSX)

S2 File. a word document explaining the column headings in the raw data.
(DOCX)

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Author Contributions

Conceived and designed the experiments: KS NW PB. Performed the experiments: KS. Analyzed the data: KS NW PB. Contributed reagents/materials/analysis tools: KS. Wrote the paper: KS NW PB.

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