Cultural Transmission: Exploring the role of language and transmission pathways in social networks

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Abstract

This thesis investigates previously underexamined or unexplored aspects of the cultural transmission process with the overall aim of advancing cultural evolutionary theory. The first study implements the linear transmission chains experimental design to systematically compare language versus demonstration as social transmission modes in adult and child chains. Despite its importance in social learning, language is extremely underexamined as a distinct mode of transmission. The results, however, illustrate that it supports the type of high-fidelity social transmission that is required for cumulative cultural evolution, especially in children. The second study examines social learning from a multi-generational perspective. By using a novel design, it investigates how the context of acquisition of a cultural trait affects the onward transmission of that trait. This is the first experimental instance in which onward transmission is examined. The findings suggest that a context-congruence bias impacts cultural transmission and it even modulates model-based biases. The context-congruence bias is the first factor found to link acquisition and onward transmission. The third study uses qualitative data to explore how cultural information flows in a real-world social network. It explains how the previously proposed transmission biases may impact acquisition and onward transmission, and how vertical congruence – the result of our proposed context-congruence bias – can lead to increased longevity and stability. By exploring cultural transmission at the level of the individual, we uncover new questions and present new hypotheses. As different social learning and teaching mechanisms are documented, their connection with trait longevity is also considered. In the final chapter, the implications of the studies are discussed, as are their possible limitations and the avenues for future research that arise from the findings.

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Chapter 1
General Introduction

This thesis investigates aspects of the cultural transmission process – some of which have not been previously examined and others have been underexplored – with the overall aim of advancing cultural evolutionary theory. Three studies comprise it: two quantitative and one qualitative. In the general introduction and literature review sections that follow, I will provide the necessary terminology, as the thesis is written for both experts and non-experts in the field to read. Afterwards, I will discuss the relevant body of work and the theory motivating the three studies, as well as the reasons why I have adopted an evolutionary framework. Finally, I will briefly present each study, I will explain how they relate to one another, and how they generally contribute to the cultural evolutionary theory.

As my focus is 'cultural transmission', it is essential to start by defining 'culture'. According to Richerson and Boyd (2005), culture consists of "information capable of affecting individuals' behaviour that they acquire from other members of their species through teaching, imitation, and other forms of social transmission" (p. 5). Social transmission is "any process of nongenetic transmission" by which cultural traits are learned (Cavalli-Sforza & Feldman, 1981; p. 7), including observation and interaction with others (Laland, 2001). Humans have been characterised as "ultra-social" animals (Herrmann, Call, Hernández-Lloreda, Hare, & Tomasello, 2007; Tomasello, 2014), an attribute that captures our identification with cultural groups and our "ultra-cooperative" (Tomasello, 2014; p.187) ways. Since infancy, psychological mechanisms are in operation which facilitate our engagement in social interactions with others and our expectation that others will socially engage with us (Tomasello, 2014; Warneken, Chen, & Tomasello, 2006). Through these, we become masterful in using the artefacts and information available in our environment, and active learners and transmitters of cultural information (Tomasello, 1999a). During social learning and transmission, culture evolves.

Cultural Evolution

Over the years, different approaches to cultural evolution have been formed (Blackmore, 2006; Claidière, Scott-Phillips, & Sperber, 2014; Dennett, 2018; Heyes, 2016a; Ingold, 2007; Sperber

& Hirschfeld, 2007; see also Acerbi & Mesoudi, 2015; Mesoudi, 2021 for a review). A very influential one of these suggests that cultural evolution can be viewed as analogous to a Darwinian evolutionary process (Acerbi, Kendal, & Tehrani, 2017; Boyd & Richerson, 1985, 2005; Campbell, 1965; Cavalli-Sforza & Feldman, 1981; Henrich, Boyd, & Richerson, 2008; Henrich & McElreath, 2003; Kempe & Mesoudi, 2014; McElreath & Henrich, 2007; Mesoudi, 2015; Mesoudi, Whiten, & Laland, 2004; Richerson & Boyd, 2005; da Silva & Tehrani, 2016; Tamariz, 2019; Tehrani, 2013; Tennie, Call, & Tomasello, 2009), as it encompasses key Darwinian properties: variation (in that, cultural traits vary between and within groups and individuals), differential fitness (because some cultural traits are more likely than others to be transmitted and acquired by groups or individuals), and inheritance (which entails the transmission of cultural traits from a transmitter to a learner) (Blancke & Denis, 2018; Derex & Boyd, 2016; Kolodny, Creanza, & Feldman, 2015; Mesoudi et al., 2004; Strimling, Sjöstrand, Enquist, & Eriksson, 2009; Whiten, Hinde, Laland, & Stringer, 2011). Within this approach, a theory known as "dual-inheritance" (Boyd & Richerson, 1988; Cavalli-Sforza & Feldman, 1981; Richerson & Boyd, 2005) posits that human behaviour and biology are the products of two different inheritance systems: the genetic inheritance and the cultural inheritance system. The two systems interact with one another, and they lead to gene-culture co-evolution, i.e., changes that occur in the culturally inherited traits of a population provoke changes in their genetically inherited traits, and vice versa (Beja-Pereira et al., 2003; Feldman, Cavalli-Sforza, & Peck, 1985; Feldman & Laland, 1996; Kobayashi, Ohtsuki, & Wakano, 2016; Richerson, Boyd, & Henrich, 2010).

Other scholars, however, disagree with the dual-inheritance theory and with the view that cultural evolution follows a Darwinian evolutionary process (Atran, 2001; Boyer, 1998; Sperber, 1996). Instead, they argue that cultural change is induced by the 'cultural attraction' (Sperber, 1996) (also referred to as the 'biased transformation' (Scott-Phillips, Blancke, & Heintz, 2018)) of cultural information. This happens at the individual level, and it follows non-random, consistent directions (Claidière & Sperber, 2007; Heintz, 2017; Lerique & Roth, 2018; Miton, Claidière, & Mercier, 2015; Morin, 2013, 2018).

There are many differences between the two positions (Morin, 2016a; Richerson, 2017; Sperber & Claidière, 2008). Perhaps the most essential to this thesis is their approach to inheritance. Scholars of the 'cultural attraction' school of thought suggest that culture is transformed and reinterpreted as it passes from the sender to the receiver (Atran, 2001; Scott-Phillips et al., 2018); in other words, cultural information is passed on by being 'reconstructed'

by the receiver (Morin, 2016b; Scott-Phillips, 2017; Sperber, 1996). On the other hand, dual-inheritance supporters argue that culture is transmitted through a process analogous to biological inheritance: the process of the transmission of cultural information from the transmitter to the learner parallels the biological transmission of genes from parent to offspring (Cavalli-Sforza & Feldman, 1973). Therefore, instead of 'reconstruction', scholars supporting the dual-inheritance theory treat cultural transmission as the process by which a learner 'copies' the cultural information of the transmitter. For dual-inheritance theorists, the difference with biological replication lies in the fact that cultural learners are biased with respect to whom, what, when and why they copy (Atkinsson, O'Brien, & Mesoudi, 2012; Chudek, Heller, Birch, & Henrich, 2012; Henrich & Broesch, 2011; Kendal, Giraldeau, & Laland, 2009; McGuigan, 2012; Price, Wood, & Whiten, 2017; Wood et al., 2016; Wood, Kendal, & Flynn, 2013).

It is not my intention to support or argue against one position or the other through my studies. It is, however, necessary to note that I have adopted the dual-inheritance approach to investigating cultural evolution, because I believe that, just as natural selection drives biological evolution, 'cultural selection' (Cavalli-Sforza & Feldman, 1981) – that is, the "small and often undirected cultural mutation followed by the selection of beneficial variants via non-random learning biases" (Mesoudi, 2021; p. 5) – is what primarily drives cultural evolution (Mesoudi et al., 2004). By consequence, when I discuss cultural transmission, I refer to the process during which a learner copies cultural information and it is this process that my thesis explores. That is not to say that I disregard completely cultural attraction theory. I believe that the most constructive approach to cultural evolution is that of scholars who attempt to reconcile the two, by presenting their more beneficial additions (e.g., see Henrich, 2004; Henrich & Boyd, 2002; Mesoudi, 2021). I do, nonetheless, aim to inform the dual-inheritance theory by identifying important gaps, addressing them, and paving the way for new approaches and new research questions.

Cultural Transmission

As mentioned above, *inheritance* (i.e., the process of cultural transmission of information to the learner) is of particular interest in the current thesis. It is also an important point of research for the dual-inheritance approach, as it is connected with cumulative cultural evolution (CCE). CCE can be defined as the retention of modifications of the transmitted information and the addition of changes by new generations of learners, which results in the formation of sophisticated products (Boyd & Richerson, 1995a; Caldwell & Millen, 2008a; Caldwell,

Renner, & Atkinson, 2017; Dean, Vale, Laland, Flynn, & Kendal, 2014; Henrich et al., 2016; Kurzban & Barrett, 2012; Legare, 2017; Mesoudi & Thornton, 2018; Tennie et al., 2009; Tomasello, 2009; Tomasello, Kruger, & Ratner, 1993b; Vaesen, 2012; Wasielewski, 2014). It is the process that leads to the cultural diversity and complexity we observe in the world and, so, it has been the focus of much invaluable research (see Legare, 2017; Mesoudi, 2015, 2017; Mesoudi & Thornton, 2018 for recent reviews), yielding conclusions such as that CCE is enabled by certain social transmission mechanisms such as teaching and high-fidelity copying[1] (for opposing views see Caldwell, Schillinger, Evans, & Hopper, 2012; Saldana, Fagot, Kirby, Smith, & Claidière, 2019; Zwirner & Thornton, 2015).

Based on previous studies, a learner can acquire cultural information from a transmitter via high-fidelity copying: she will retain and reproduce the input information with high-fidelity (a process which will be referred to as 'imitation'[2] from this point on) and she will even include the elements of the behaviour whose causality are cognitively opaque to her, regardless of whether she questions their causality (a phenomenon termed 'overimitation'; Berl & Hewlett, 2015; Clay & Tennie, 2018; Lyons, Damrosch, Lin, Macris, & Keil, 2011; Lyons, Young, & Keil, 2007; McGuigan, 2012; McGuigan & Graham, 2010; McGuigan, Makinson, & Whiten, 2011a; McGuigan & Whiten, 2009; Nielsen & Tomaselli, 2010) or not (regarded as 'blanket

[1] 'Copying'

The term itself has previously been treated as a synonym of the term 'replication', which is commonly associated with biological evolution (see Heyes, 2018 for a review), and its usage in the context of cultural evolution has been debated (Godfrey-Smith, 2000; Lewens, 2004). There is not a clear terminology accepted by researchers of both the dual-inheritance theory and cultural attraction theory for cultural inheritance. It is, however, essential to the thesis to describe how it will be used. By borrowing some of the core ideas of Heyes (2018), 'copying' in the current thesis is treated as the presence of cultural information (e.g., a behaviour) in the learner's output (i.e., the learner performs the behaviour) *because* it was present her input (i.e., the learner has observed a transmitter demonstrate the behaviour) (Godfrey-Smith, 2000; Hull, 2010; Tamariz, 2019).

[2] 'Imitation'

This is another term whose meaning and usage have been debated in the past (Dean et al., 2018). For the purposes of this thesis, I use 'imitation' as a synonym of the broader term 'copying' (see above), and I regard it as a mechanism of social learning (Caldwell & Whiten, 2002; Dean et al., 2018), during which an individual "B learns some part of the form of A's behaviour" (Whiten, 2000); p.481).

copying'; Horner & Whiten, 2005; Lyons et al., 2007; McGuigan, 2013; McGuigan et al., 2011a; McGuigan, Whiten, Flynn, & Horner, 2007).

I will argue that copying of cultural traits does not necessitate that these are modelled for a learner to observe visually, as it can also happen though language (e.g., the transmitter provides verbal descriptions of his actions, and a learner copies them based on the descriptions). This may, initially, appear in contrast with previous papers listing 'imitation' and 'language' as distinct social learning mechanisms, with the latter sometimes being included in 'teaching' (Caldwell & Millen, 2009; Mesoudi & Whiten, 2008a; though see Heyes, 2011 for the position that teaching, including through language, is not a social learning mechanism). Again, this depends on one's definition of 'imitation'. I consider imitation to be enabled by different modalities. As per the definitions provided above (see 'Copying' and 'Imitation' boxes), a learner can imitate a transmitter's cultural traits when she has observed the transmitter demonstrate them. For example, a child (learner) observes her mother (transmitter) rubbing some antiseptic gel on her hands after washing them (cultural trait), so she does the same after she washes her hands (visually enabled imitation). However, imitation of a transmitter's cultural trait by the learner can also be considered when that trait is present in the learner's output (e.g., the child rubs antiseptic gel on her hands after washing them) because it was present in her input in a linguistic form (e.g., the mother-transmitter told her child that she herself had rubbed antiseptic gel on her hands after she washed them). So, imitation can be both visually (via demonstration) and auditorily (via verbal descriptions) enabled. By extension, we could consider language to be a mechanism of cultural transmission, but not one that is always distinct from imitation and not one that is always included in teaching.

Even though language can be a key mode of social transmission (Hewlett, 2016; Mesoudi & Whiten, 2008a), its distinct effects on acquisition and cultural evolution are extremely under-explored. Of the few studies that examine linguistic transmission, most include it in addition to other modalities, such as modelling, gesture, and other visual cues (Caldwell & Millen, 2009; Dean, Kendal, Schapiro, Thierry, & Laland, 2012; Morgan, Uomini, et al., 2015; Ohnuma, Aoki, & Akazawa, 1997; Putt, Woods, & Franciscus, 2014; Zwirner & Thornton, 2015). In this thesis, I will address this gap by incorporating linguistic transmission in an experimental design (see Chapter 2 below) and systematically comparing it to demonstration, which is a commonly used method to model cultural transmission in the lab.

Studying cultural transmission

To study cultural transmission in the lab or with computer simulations, researchers have used different experimental designs (Mesoudi, 2007; Mesoudi & Whiten, 2008a; Whiten & Mesoudi, 2008). One of these is the linear transmission (or diffusion) chains design (Flynn, 2008; Flynn & Whiten, 2008; Hopper, Flynn, Wood, & Whiten, 2010; McGuigan & Cubillo, 2013; McGuigan & Graham, 2010; Nielsen, Cucchiaro, & Mohamedally, 2012). Typically, in this design, the first participant (learner) of the chain observes a cultural trait, such as the behaviour of extracting a reward from a box, and is, afterwards, asked to reproduce it (i.e., to extract the reward from the box). The first participant's reproduction (the transmitter in this instance) is observed by the second participant (new learner) in the chain, who is asked to reproduce it. The third participant (new learner) observes the reproduction of the second participant (transmitter) and so on until all the participants in the chain have reproduced the behaviour. This has been described as the simplest method for modelling and studying cultural transmission (Mesoudi & Whiten, 2008a), as the design itself does not allow for, e.g., interactions within generations (transmitter-transmitter interaction or learner-learner interaction) or the socialisation of new learners into a group of transmitters.

The studies implementing a *replacement* chains design (Baum, Richerson, Efferson, & Paciotti, 2004; Caldwell & Millen, 2008b; Insko & et al, 1983), on the other hand, incorporate some of these "complexities". In such studies, a group of learners represents the first cultural generation, who are asked to complete a task or play a game. Then, a participant is replaced by a new participant who joins the group, thus initiating the second generation. One by one, each participant is replaced with a new one and with each replacement a new cultural generation is formed. In a different experimental design, the closed-groups design (Efferson et al., 2007; Efferson, Lalive, Richerson, McElreath, & Lubell, 2008; Kameda & Nakanishi, 2002, 2003; Mesoudi & O'Brien, 2008a), participants also engage as a group with a task or a game. The difference with the replacement method is that no participant is replaced. The initial group of participants is studied, and their learning opportunities are what is manipulated by the experimenter (e.g., who transmits and to whom).

Apart from laboratory studies and computer simulations, naturalistic studies have been conducted to explore cultural transmission in real-world settings and with real cultural traits (Aunger, 2000; Greenfield, Maynard, & Childs, 2000; Hewlett, DeSilvestri, & Guglielmino, 2002; Lozada, Ladio, & Weigandt, 2006; Ohamgari & Berkes, 1997). Naturalistic studies of

cultural transmission could be considered the most complex ones, as the researchers do not have control over the variables or a way to manipulate them, and real-world cultural traits, with all their complexity and sophistication, are examined. In contrast, laboratory and computer models allow researchers to control and manipulate many variables, but they only investigate artificial, simple cultural traits. Thus, despite the lack of control, naturalistic studies are of utmost importance to the field, because they allow us to view the cultural transmission – and evolution – process as it actually happens in real populations with real cultural traits.

Based on the advantages and disadvantages of the methods mentioned above, I agree with scholars suggesting that the combination of different research designs is the most productive and effective approach to studying cultural transmission (e.g., Mesoudi, 2015; Mesoudi & Whiten, 2008a). It is for this reason that my thesis also combines two experimental studies – each implementing a different design – with a naturalistic study, to uncover new factors affecting cultural transmission and to examine already established ones from a different perspective.

Selective social learning – Biased Transmission

As stated above, dual inheritance theory posits that cultural transmission is a biased process, and learners are selective when it comes to copying cultural information. Selective social learning has often been found to be the most adaptive strategy from an evolutionary perspective (Kendal, Coolen, van Bergen, & Laland, 2005; Laland, 2004). According to Laland (2004), for social learning to be adaptive, learners "ought to be selective with respect to the circumstances under which they rely on social learning and the individuals from whom they learn" (p. 4-5). For example, children's tendency to copy the cultural information provided by adults over that provided by other children (Wood, Kendal, & Flynn, 2012), may be an adaptive strategy, because an adult is more experienced and knowledgeable (Reyes-Garcia et al., 2008) and, therefore, the information of adults could be more accurate than that of children.

Boyd and Richerson's theoretical models (Boyd & Richerson, 1988; Richerson & Boyd, 2005) examine such strategies that can prove to be adaptive for social learners. Their pioneering work proposes a set of biases that operate on cultural transmission, and that can be used to predict which cultural traits new learners will adopt for themselves. Their work has informed a great deal of research, which focuses on examining their proposed types of biases: model-based biases (Chudek et al., 2012; Reyes-Garcia et al., 2008; Wood et al., 2012, 2013), content-based

biases[3] (Mesoudi & Whiten, 2008a), and frequency-based biases (also known as 'conformity bias' and 'anti-conformity bias') (Kandler & Laland, 2013; Kendal et al., 2009; Morganand & Laland, 2012; Whalen & Laland, 2015).

It is one of the main objectives of this thesis to go beyond their proposed model-based biases – according to which the probability that learners will acquire a variant is dependent upon the characteristics of the model displaying it (such as age, gender, prestige etc.) (Boyd & Richerson, 1985; Henrich & McElreath, 2003; Mesoudi & O'Brien, 2008a) – by extending the cultural transmission process to include both acquisition and onward transmission (i.e., which cultural variants learners will choose to transmit onward to other learners). In doing so, this thesis aims to fill a large gap in the literature, as onward transmission conditioned on the context of learning has not, yet, been explored.

To achieve that, we implemented Cavalli-Sforza and Feldman's (1981) proposed cultural transmission pathways within our studies (i.e., the idea that cultural information can follow different pathways, according to who is the transmitter and who is the learner). These are the vertical pathway, in which information is passed on from a parent to their child, the horizontal pathway, in which a member of one generation passes information to another member of the same generation, and oblique pathway, in which a member of one generation passes information to an unrelated member of a successive generation. In the third chapter of the thesis, we dichotomise explicitly the transmission pathways into vertical and horizontal, with vertical transmission to include oblique transmission as in some previous studies (e.g., Nielsen et al., 2012; Pagel & Mace, 2004; Theisen-White, Kirby, & Oberlander, 2011).

As can be derived from the above, then, this thesis will adopt an evolutionary framework to provide explanations about current cultural phenomena. There are still many unanswered questions and gaps in the literature (Heyes, 2018; Mesoudi et al., 2004; Perry et al., 2021). As Richerson and Boyd (2005) argue in the final chapter of their book "Nothing about culture

[3] Content-Based Biases

Boyd and Richerson's proposed 'content-based' biases have been the focus of cultural attraction theorists (e.g., see Atran, 1998; Buskell, 2017; Claidière, Scott-Phillips, et al., 2014; Sperber, 1996). Mesoudi and Whiten (2008a) attribute this phenomenon to the resemblance of the effects of content-based biases to Sperber's (1996) position that the reconstruction of cultural representations is done in a way that these representations become more similar (in content) to a cultural attractor.

makes sense except in the light of evolution" (p. 252), only when we uncover the processes and the mechanisms which lead to the evolution of our cultures from their past forms to their present ones, can we begin to understand our institutions, our behaviours, even aspects of our biology, and become able to produce explanations to today's cultural phenomena – such as the diversity of cultural traditions between populations and the similarities within those – and identify the causes of societal issues, such as inequalities, political extremities, conspiracy theories etc, with the aim of enhancing our understanding and informing interventions.

Literature Review

Human Culture is Cumulative

The evolution of human culture has been found to be cumulative (Boyd & Richerson, 1995b; Dean et al., 2014; Henrich et al., 2016; Mesoudi & Thornton, 2018; Nakahashi, 2014; Nielsen, 2018) with Tomasello arguing that it follows what he called a "ratchet effect" (Tomasello, 1999b). According to this, each new generation of learners acquire cultural information from the previous generations, and they may add or modify aspects of that information. In doing so, they may generate new, different, and more complex (Mesoudi & Thornton, 2018; Tennie et al., 2009; Tomasello, 2001) or adaptive (Henrich et al., 2008; Tamariz, 2019) cultural variants. If these innovations are transmitted to the succeeding generations, this process will yield products of such complexity and sophistication that no single individual or generation could have invented on their own (Boyd & Derex, 2015; Boyd et al., 2011; Tomasello et al., 1993a).

From the above, at least two preconditions for cumulative cultural evolution (CCE) can be identified. Legare and Nielsen (Legare & Nielsen, 2015) refer to these – imitation (i.e., the ability of learners to copy the cultural traits of the transmitters with high fidelity) and innovation (i.e., the ability of learners to innovate and improve upon that information) – as the dual engines of cultural learning and they emphasise their contribution to CCE. Specifically, innovation ensures our cultural adaptation to changing and novel environments through the introduction of new variants and the modification of existing ones (Legare & Harris, 2016), while imitation enables the conservation of cultural traits across successive generations, with the authors proposing that "transmission of cumulative culture across generations can be seen, in part, as a by-product of our propensity for high fidelity imitation" (p. 689).

Comparative studies over the last three decades have contrasted the human tendency to rely primarily on *imitation* – i.e., to focus on copying behaviours – with the tendency of non-human primates to switch between social learning strategies and, often, to employ emulation – i.e., to focus on copying the goals or outcomes, rather than the exact behaviours (Call & Tomasello, 1994; Call, Carpenter, & Tomasello, 2005; Call & Tomasello, 1995; Custance, Whiten, Sambrook, & Galdikas, 2001; Horner & Whiten, 2005; Myowa-Yamakoshi & Matsuzawa, 1999; Nagell, Olguin, & Tomasello, 1993; Tennie, Call, & Tomasello, 2006; Whiten, McGuigan, Marshall-Pescini, & Hopper, 2009). As cumulative culture is extremely rare

(Saldana et al., 2019) or, even, non-existent in non-human animals (Dean et al., 2014; Tennie et al., 2009), our species' capacity for high-fidelity imitation has been hypothesised to be a necessity for CCE[4]. This hypothesis has been studied in depth, with many scholars suggesting that high-fidelity imitation may be a key cognitive capacity for CCE (Boyd & Richerson, 1995a; Legare & Harris, 2016; Legare & Nielsen, 2015; Lewis & Laland, 2012; Nielsen, 2018; Tomasello, 2009; Tomasello et al., 1993a; Wasielewski, 2014; though see Henrich et al., 2008).

Other scholars disagree with this position (e.g., Caldwell & Millen, 2008a, 2009). Caldwell et al.'s (2012) results have led them to argue that imitation may not be as necessary to CCE as previously argued, because high fidelity transmission can be achieved via emulation, as well. Specifically, they found that high-fidelity emulation – i.e., the faithful copying of the result of a series of behaviours and not of the behaviours themselves – can induce cumulative culture. As the task in their experiment was highly transparent, though, their participants could easily infer the intermediate actions necessary to completing it. The authors also highlight that emulation learning cannot lead to high fidelity transmission of behaviours that "leave no physical trace" (such as communicative gestures) and, in these cases, imitation may be necessary.

Saldana et al. (2019) take a different perspective than that of researching whether high-fidelity imitation is necessary to CCE. They suggest that previous experiments in which individuals copied the target behaviour with low fidelity in the first generations and increasing fidelity in succeeding generations (Beckner et al., 2017; Claidière, Smith, Kirby, & Fagot, 2014; Kirby, Cornish, & Smith, 2008) could be construed as arguments that high-fidelity imitation is, in fact, a product of CCE – that is, CCE leads to high-fidelity imitation and not the other way around. Nonetheless, their experiment and the studies they cite to support their suggestion implement a particular design which could be problematic for it. The first generations in these studies are initiated with a complex artificial behaviour, such as very specific puzzle sequences or 'alien'

[4] Claims of non-human cumulative cultures have been made in the past (Beckner, Pierrehumbert, & Hay, 2017; Grant & Grant, 2010; Hunt & Gray, 2003; McGrew & McGrew, 2004). However, these remain controversial and are widely disputed (Dean et al., 2014; Marshall-Pescini & Whiten, 2008). Reasons for their dispute include that the studied traits are not necessarily the product of repeated cultural transmission, that they could possibly be invented by a single individual due to their simplicity, they are too rudimentary compared to the products of human CCE, and that their observed variation could be attributable to cultural drift (Dean et al., 2014; Whiten, 2011).

languages with no apparent structure. These behaviours are, then, transmitted to the first generations and they become more simplified and/or more structured after they are forced through the learning bottleneck (i.e., the learners' memory constraints etc.). This merely means that the initial behaviours were too "unlearnable", making learners unlikely to imitate them with high fidelity and making the first generation much more likely than the succeeding ones to leave out of their output (i.e., what they produce) the more complex elements. So, the fidelity variable in these studies may be confounded during the first transmission events (i.e., from the seed to the first generation) and inferences regarding the connection between high-fidelity imitation and CCE would be more informative after the second generation's output. Alternatively, before running an experiment, it could be beneficial to ensure that the initial behaviour is learnable, by asking participants during a pilot phase to "copy exactly what the previous person did/say/write etc."[5].

The above example illustrates the need for specificity when discussing CCE. For instance, we know that CCE can lead to systematicity, complexity and adaptation (see above). Each of these attributes may be the result of a different one of the above-mentioned processes – i.e., high-fidelity imitation and emulation, and innovation – and, therefore, it may be difficult to decipher each process's necessity to CCE without accounting for the others. The current thesis will examine closely these processes, with the second chapter specifically examining both imitation and innovation during the cultural transmission of a learnable task, and the fourth chapter exploring in depth imitation, emulation, and innovation in a naturalistic setting.

The role of Overimitation

During cultural transmission, new learners have been found to acquire even the elements of the information whose functionality and causality are cognitively opaque to them (Csibra & Gergely, 2011; Wasielewski, 2014). An example of that would be when the parents of a young child/learner transmit to her the ways of making someone's acquaintance. During this, the learner is, most likely, both able to and willing to reproduce all the steps, including e.g., asking

[5] This instruction was used during the piloting phases of the first two studies included in this thesis. However, during the experimental phase, no participant received this instruction. Instead, they were asked to "have a go" at the task (Study 1) or, to teach someone "a solution to the problem" (Study 2). As Caldwell and Millen note, for any laboratory model of cultural evolution to be valid, it is "important that participants understand that the choice of whether or not to copy is their own" (p. 3534).

the normative – and apparently unnecessary – question "how do you do?" and extending her hand out to shake her interlocutor's hand. She may not understand the functionality of asking a question to which one does not expect an answer, nor the causality of a handshake when it comes to learning someone's name. She, nevertheless, reproduces these two elements, along with ones she may find useful and functional (e.g., asking someone's name, giving her own name, observing faces, and memorising them and so on).

The learner in this example reproduces *everything* with high-fidelity. In the literature, this is not simply called "copying" (or "imitation"). Instead, it is called "blanket copying". This term refers to tendency of learners to reproduce every behaviour they observe, regardless of whether these are functional or useful or not and of and whether information of their functionality/usefulness is available or not (Evans, Laland, Carpenter, & Kendal, 2018; McGuigan et al., 2011; Whiten et al., 2009). An essential aspect of blanket copying, "overimitation", specifically refers to the instances in which learners may question the functionality or necessity of actions but proceed to copy them with such high fidelity as to compromise efficiency (Lyons et al., 2007).

Overimitation has been the subject of much recent investigation (see Hoehl et al., 2019) for a recent review) and it has been explored across different age groups (see below). Many of these studies involve modelling a sequence of actions (performed by either the experimenter or trained participants) which lead to the completion of a task for participants to observe. Typically, some of the actions are necessary to the completion of the task ('causally relevant') while others are not ('causally irrelevant'), i.e., the task can be completed without them and, therefore, they only increase the time and energy needed to complete it and reduce efficiency.

In a classic such study, Horner and Whiten (2005) compared chimpanzees' and three to four-year-old children's imitative and emulative tendencies when using a novel reward-retrieval task. The participants saw the model (a human demonstrator) perform a sequence of actions (two causally relevant and two causally irrelevant) that resulted in the extraction of a reward from a box. Afterwards, they were allowed to interact with the box. Participants were allocated to one of two conditions, based on the box with which they interacted: either in the transparent box condition, in which the effects of the actions could be observed (and, therefore, the participants could infer the causal relevance of each action), or in the opaque box condition, in which the effects of the actions could not be observed (and, so, the causality of each action was cognitively opaque to participants). Results showed that, in the opaque condition, both the

children and the chimpanzees copied some of the causally irrelevant actions that they had observed. In contrast, when interacting with the transparent box, the chimpanzees would ignore the causally irrelevant actions, whereas children would copy still copy some of them with high fidelity. So, chimpanzees would switch to copying only the relevant actions (i.e., emulate the result) when information about causal relevance was visibly accessible, whereas human children would imitate the model, as they would readily copy both causally relevant and irrelevant actions in either condition.

This finding may speak to the case made for the connection between (over)imitation and CCE. If our closest relatives, chimpanzees, are more likely to emulate when they perceive aspects of a behaviour as unnecessary, then cultural traditions – which can be often cognitively, functionally, or causally opaque to learners (see above) – would not survive within their populations. In fact, they may not even survive one generational succession. In contrast, humans copy those aspects, thereby preserving them within their own generation and enabling their transmission to succeeding ones. Perhaps, then, human uniqueness does lie in "blanket" copying (Whiten et al., 2009). Perhaps the unique cumulative aspects of our culture are, indeed, the result of our tendency to copy what we observe with high-fidelity, even if that means we overimitate.

Findings from previous studies suggest that the tendency to overimitate is evident in a variety of cultures (Berl & Hewlett, 2015; Nielsen, Mushin, Tomaselli, & Whiten, 2014; Nielsen & Tomaselli, 2010) and it may, in fact, follow a developmental increase, with older children overimitating more than younger children (Berl & Hewlett, 2015; McGuigan et al., 2011, 2007; McGuigan & Whiten, 2009; Moraru, Gomez, & McGuigan, 2016) and adults overimitating more than children overall (Berl & Hewlett, 2015; McGuigan et al., 2011a). For instance, Berl and Hewlett (2015) investigated how hunter-gatherer children and adults from the Central African Republic behaved when presented with an adult performing a sequence of causally relevant and irrelevant actions in a box similar to the ones in the experiments above. They found that the adults overimitated much more frequently than the children did.

Though this could be attributable to the children being reluctant to copy a much older – and, thus, too different than themselves – model, as they have been found to show a preference for copying children over adults in some contexts (Wood et al., 2016; Zmyj, Aschersleben, Prinz, & Daum, 2012), studies have demonstrated the children's tendency to overimitate adult models (e.g., McGuigan et al., 2007) and not to overimitate other children (e.g., Flynn, 2009).

As stated above, overimitation enables the transmission of information with high fidelity across generations (Tennie et al., 2009; Tomasello, 1994, 1999b), and studies have explored its role in CCE, by implementing the transmission chain paradigm. In this, one generation (e.g., one participant or a group of participants) passes on a cultural trait (e.g., a solution to a problem, a story etc.) to another generation. For example, Flynn (2008) allocated 2- and 3-year-old children in linear transmission chains, where each child represented one generation. The first child in each chain – i.e., the seed – was trained by the experimenter to produce a sequence of causally relevant and causally irrelevant actions, which led to the extraction of a reward from a box and with which all chains were initiated. The seed modelled the actions for the next child in the chain – i.e., Generation 1 (Gen1). The seed left the room and Gen1 interacted with the box. Afterwards, Gen2 (another child) entered the room and witnessed the last two interactions of Gen1 with the box. This was repeated until six children (or six generations) had completed the task. In this study, the same apparatus used in Horner and Whiten (2005) and McGuigan et al. (2007) was used. However, contrary to the two dyad studies, Flynn (2008) observed that younger children did not overimitate as much, as they omitted causally irrelevant actions from their output. Thus, efficiency accumulated over generations, with each succeeding one completing the task at hand with fewer causally irrelevant actions than the previous in both the opaque and the transparent box conditions and in both age groups. This would suggest that 2- and 3-year-olds do not overimitate when the model is a child of the same age.

However, when McGuigan and Graham (2010) implemented the same linear transmission chain design and recruited 3- and 5-year-old children, they found that 3-year-olds overimitated in all cases. Nonetheless, contrary to the results of McGuigan et al. (2007), who found that 5-year-olds overimitated the adult model in both the opaque and the transparent box conditions, McGuigan and Graham (2010) also found that 5-year-olds only overimitated in the opaque box condition, and not in the transparent box condition. This may suggest that the children in the 2010 study behaved more "rationally" (not wasting time and energy performing causally irrelevant actions) or perhaps that they were less inclined to copy the child models in the 2010 study than the adult models in the 2007 study.

Recently, scholars aiming to explain our capacity for such high-fidelity imitation as to overimitate in a variety of contexts and cultures, as well as our tendency not to rely as much on it in others, have focused on the nature of the transmitted behaviour. Studies have shown that, when learners interpret a behaviour as conventional/ritual, they (over)imitate it with higher fidelity than when they interpret it as instrumental (Herrmann, Legare, Harris, &

Whitehouse, 2013; Legare, Wen, Herrmann, & Whitehouse, 2015; Watson-Jones, Legare, Whitehouse, & Clegg, 2014; Yu & Kushnir, 2014). In their review, Legare and Nielsen (2015) argue that high fidelity imitation decreases for instrumental learning, which allows flexibility and an increase in innovation. This flexibility is much rarer in conventional learning; thus, innovation stays low and high fidelity imitation is preserved. Clegg and Legare (2016a) conclude that the learners' interpretation of a behaviour as conventional or instrumental has great implications for both what these learners acquire and what they transmit onward to others. As stated in the Introduction, onward transmission has not been examined before and, therefore, more research is necessary to support their conclusions.

Transmission mode and (Over)imitation

I agree with scholars who argue about the significance of the nature of the behaviour and its effects on (over)imitation. Nonetheless, I do not support that this is the sole factor affecting the degree of imitative fidelity. The design of social learning lab studies can also constitute an important factor. The studies discussed thus far employ a demonstrative transmission mode during the social learning process of the target behaviours. The participants first visually observe a model – either an experimenter, a confederate, or a different participant – demonstrate a behaviour, e.g., a sequence of actions, which lead to the completion of a task. Then, the fidelity with which they reproduce that behaviour and the innovations[6] they introduce to it are examined and measured. This is, certainly, a valid approach during the designing of social learning laboratory studies as, according to Bandura (1972), new learners can acquire complex behaviours provided that they find themselves in social contexts where they can

[6] 'Innovation'

Some scholars have highlighted the importance of distinguishing between the terms 'innovation' and 'invention' (Hochberg, Marquet, Boyd, & Wagner, 2017; McGuigan et al., 2017; Reader, Morand-Ferron, & Flynn, 2016). According to this distinction, when an individual produces a novel behaviour or trait, it is considered an 'invention'. When that invention becomes diffused in the population it becomes an innovation. The population-level innovation defined as such, constitutes the essential engine for cultural evolution. Nonetheless, as lab experiments cannot, always, include enough generations to ascertain whether the inventions of participants become diffused in their chains (as per the study in Chapter 2, where each chain consisted of three participants), 'innovation' in this thesis is treated as a synonym for the above definition of 'invention', as in some previous studies (Carr, Kendal, & Flynn, 2015; Whiten & Flynn, 2010).

observe another individual perform those behaviours, and most of our behaviour we learn observationally through modelling (Bandura & McClelland, 1977).

Besides visual demonstration, however, language is also considered a key channel of social transmission (Laland, 2017; Legare, 2017; Tomasello et al., 1993a). Consider the example of how a young child may learn how to make someone's acquaintance provided above.

The learner may have learned the behaviour through observing others in her social environment demonstrate the behaviour and then, reproducing it. It is equally likely, however, that she learned it through the provision of verbal instructions (such as "then, you give out your hand to shake the other person's hand") by her parents and then, the production of the intended behaviour. (Over)imitation, i.e., a mechanism of cultural transmission, could, therefore, be enabled by different modalities, including language[7] and demonstration.

In fact, studies in which participants produced verbal instructions in addition to demonstration while culturally transmitting a behaviour to a learner, produced results that support that language increases copying fidelity (Putt et al., 2014) and it is required for cumulative culture

[7] Language Evolution Theories

Different theories have been put forth regarding the evolution of our species' capacity for language, which could have different implications for the connection between language and cultural evolution. For instance, the Darwin-inspired (Darwin, 1872, 2008) *'musical protolanguage'* hypothesis (Fitch, 2006) adopts a comparative approach which focuses on the biological evolution of the vocal control of vocal learners, such as humans, songbirds, and cetaceans (Fitch, 2006; Janik, 2014; Janik & Slater, 1997) and it accepts Darwin's (1872) proposal that this musical protolanguage had initially evolved for sexual and territorial display. This hypothesis posits that language and music may share a common ancestor and the very important feature of cultural transmission, during which they are shaped, and they evolve (Kirby, 2012). Supporters of this hypothesis may argue that language is the product of cultural evolution (as is music) and, therefore, the capacity for "demonstration-enabled" imitation would have evolved before "verbally-enabled" imitation. However, supporters of the 'gestural origins' hypothesis, would support that language began as a gestural system first, before also becoming a vocal communication system, as the iconicity of the signals/gestures would later enable the development of symbols and the arbitrariness of vocal communication (Arbib, 2005; Corballis, 2003; Hewes, 1992; Sterelny, 2012; Tomasello, 2008). At this point, it should be clarified that this thesis does not focus on language evolution and its connection with cultural evolution per se (other than the first study allowing us to infer relevant conclusions due to its methodology and results), yet it is necessary to note that we treat demonstration and language as distinct modalities that can support cultural transmission. Additionally, we treat language as a mechanism for cultural transmission (Smith & Kirby, 2008).

(Dean et al., 2012). In Morgan et al.'s stone tool-making study (2015), participants were arranged into transmission chains, which were allocated in five conditions according to the transmission mode employed. These included demonstration, gestural teaching, and verbal teaching (in which transmitters provided verbal instructions to the learners in addition to gestural teaching and interaction). Participants in the verbal teaching condition performed better than participants in the other conditions (though the improvement in participant skill was not statistically significant when compared to the gestural teaching condition) and the authors concluded that language allows both the transmission of the skill itself with high fidelity and of the ability to transmit effectively the skill to others.

On the other hand, in another transmission chain study where participants were tasked with producing Levallois stone tools (Ohnuma et al., 1997), participant performance did not differ between the demonstration-only group and the demonstration-plus-verbal-instructions group. In addition, in Zwirner and Thornton's (2015) study, in which participants constructed baskets to carry as much rice as possible, language (in the form of verbal instructions) was not essential for cumulative improvement, despite leading to the construction of more robust baskets than the imitation (in which learners solely observed the actions of others) and emulation conditions (in which learners could only observe the finished product). Similarly, in a transmission chain study where participants were asked to make paper aeroplanes that would fly as far as possible (Caldwell & Millen, 2009), performance improved over chains to a similar degree in the imitation (in which participants observed both the process of making an aeroplane and the finished product), emulation (in which participants saw only the finished aeroplanes and not the process of their making), and teaching (i.e., verbal instructions in addition to gestural teaching) conditions.

So, with regards to the mode of cultural transmission, there have been contrasting views as to whether language allows for higher degrees of fidelity during transmission and whether it is necessary to cumulative culture or not. Yet, the distinct effects of language on cultural transmission and, subsequently, CCE have not been explored in the above studies. Rather, language is grouped with another transmission mode, such as demonstration or gesture. A direct comparison of how faithfully a target sequence of actions is culturally transmitted when participants only have access to demonstrated actions versus when they only receive, e.g., verbal instructions, is needed for us to be in a position to make inferences regarding the role of language in cumulative culture.

In summary, two of the inconsistencies in the CCE literature can be identified from the studies focusing on (over)imitation and those which make direct comparisons between different transmission modes. First, the proposed developmental increase in the tendency to overimitate is not always evident (e.g., see McGuigan & Graham, 2010). Yet, even in some studies in which it is (e.g., McGuigan et al., 2011; Whiten et al., 2016), the adult participants (whose copying behaviours produce results that allow the authors to conclude that adults overimitate more than children do), are of various ages. For example, in the study of McGuigan et al. (2011), the adult group consisted of participants aged 20 to 63 years old. Similarly, in the naturalistic study of Whiten et al. (2016), the adult group consisted of participants aged 16 to 62 years old. Overimitation has not been sufficiently examined (to our knowledge) with adult participants organized in smaller age groups (e.g., 18 to 35 years old), in order to account for the developmental increase in overimitation. In addition, although the children in previous overimitation studies have been given specific instructions that focus on task completion (e.g., Horner & Whiten, 2005), overimitation studies with adult participants have yet to provide as much prior instruction to them as to children (McGuigan, 2012). This may be one of the reasons behind the increased degree of overimitation found in adults in comparison to children, as adults are more focused on the process than on task completion, while children may focus on task completion. Second, the distinct effects of language (for example, in the form of verbal instructions) as a mode of transmission on the dual engines of cumulative culture – i.e., (over)imitation and innovation – are extremely understudied. Subsequently, we cannot make inferences about the role of language in CCE, despite it being a key channel of social transmission.

Transmission biases on (Over)imitation

In this thesis, both of the above gaps in the literature are addressed. The findings add to the current volume of research suggesting that humans do tend to learn by copying others with high fidelity to the point where they overimitate their behaviours (Hoehl et al., 2019; Lyons et al., 2011, 2007; McGuigan et al., 2011a).

However, the findings also support the proposition that humans copy others selectively (Kendal et al., 2018; Wood et al., 2013) and different factors can determine when they will choose to socially learn behaviours, how, by whom and so on. The first study specifically demonstrates, for example, that the transmission mode and the age of the learner can influence the process of social learning: children are more likely to copy even causally irrelevant actions (i.e.,

overimitate) performed by the transmitter when the latter transmits the behaviour through language, whereas adults are more likely to overimitate a transmitter when they observe him/her model them, i.e., through visual demonstration (see Chapter 2 below).

Selective social learning and Biased transmission

Other factors that can influence a learner's decision to learn the transmitted information have been proposed as well, including the transmitter's competence (Corriveau & Harris, 2009; Corriveau, Kinzler, & Harris, 2013; Jaswal & Neely, 2006), consensus (Morgan, Laland, & Harris, 2015), task difficulty and cost of asocial learning (Kendal et al., 2018; Morgan, Rendell, Ehn, Hoppitt, & Laland, 2012), number of transmitters of the information (Morgan et al., 2012) etc.

When discussing her findings and those of previous studies, McGuigan (2012) argues that the overimitative behaviour of a learner is influenced by certain 'heuristics', such as the properties of the task, the characteristics of the transmitter and the learner's age. Drawing insights from Richerson and Boyd's proposal that evolution has facilitated the development of cognitive mechanisms – or transmission biases – which allow individuals to acquire adaptive cultural traits through observation (2005), McGuigan suggests that these heuristics – which she matches to Richerson and Boyd's transmission biases – interact and determine overimitation, which "is an overextension of a highly adaptive capacity for acquiring culture" (2012; p. 158).

Richerson and Boyd can be considered pioneers when it comes to the mathematical modelling of how cultural transmission can be biased (2005). They proposed a set of specific cognitive biases that can affect the acquisition and cultural transmission of particular variants over others. One of these is the content-based bias, which explains what the learner acquires. According to this, when there exists more than one variant of the same behaviour – e.g., two different ways to solve a problem – an individual's likelihood of copying one variant over its alternative(s) is affected by the intrinsic properties and characteristics of that variant. For instance, we might be more likely to learn and apply the solution that is the least time-consuming, the most learnable, the most memorable, etc.

In addition to this, they introduce frequency-based biases, such as biases for "conformity" and "anti-conformity", which also influence what the learner acquires. According to these, the probability that a cultural variant will be adopted by the young generation of learners is affected by the number of members of the population who display that variant, or the number of times

that the specific variant is displayed. For example, a student might be biased to adopt the cultural variant that twenty of her classmates exhibit over the one exhibited by two of her classmates (conformity bias). Similarly, a person may choose to adopt the variant exhibited by a small fraction of the community, over the one that most members exhibit (anti-conformity bias).

Finally, Richerson and Boyd (2005) introduce model-based biases. These influence whose behaviour is more likely to be culturally transmitted – i.e., from which member(s) of the transmitting generation, the generation of learners is most likely to prefer to learn. According to model-based biases, the characteristics of a model/transmitter make the learner more likely to show a preference for learning the variant that he/she displays. For instance, learners may be biased to acquire the variants displayed by older models (Henrich & Gil-White, 2001) or models who have been successful in a task (Reyes-Garcia et al., 2008).

Wood and colleagues (2012) have also demonstrated that the human tendency to copy others is affected by innate heuristics, or transmission biases as well as how these facilitate the cumulative evolution of behaviours. The results from their experimental study (2012) suggest that, since the young age of five, children demonstrate selective social learning strategies, as they show a preference for faithfully reproducing an adult model's causally irrelevant actions over those of a perceived task-proficient child. The authors conclude that not only is overimitation affected by transmission biases but, also, that one bias (in their study, a 'copy-adults' bias) can be favoured over another (in their study, a 'copy task-knowledgeable-individual' bias).

In a later review (Wood et al., 2013), they analyse evidence for the existence of different model-based biases underlying transmission, which affect children's decision of which models to copy. In this, they discuss both studies whose results imply that children may be biased to copy individuals whom they perceive to have higher status and studies implying that children may be biased to copy individuals whom they perceive to resemble themselves. At first, these biases may appear contradictory, as the first would imply a bias to copy-someone-different (higher status) and the second a bias to copy-someone-similar-to-self (e.g., another child, perhaps of the same age and gender).

Social learning is, however, a complex process which, as can be attested from the discussion thus far, is dependent on multiple factors which still evade our understanding. Though Richerson and Boyd's proposed biases have revolutionised the way we view and test cultural

transmission mechanisms, their work is not conclusive. Much more research is needed, which will not solely focus on identifying cultural transmission biases and their direction, but that will also promote our understanding of their processes, including how and when one can override the other, and how their interactions affect cumulative culture.

Biased Transmitters and Biased Learners

It can be illuminating to consider additional dimensions of the previously proposed biases. Thus far, one dimension has been the focus of research and experimentation: the biases imposed on the learner during his/her acquisition of a cultural trait. These investigate questions such as what the learner prefers to copy and from whom. So, when considering, for example, the differences between a mother and a father from the perspective of their child/learner, we would, most probably, focus on their gender first. We would expect that a daughter would be more likely to copy and learn from the mother than from the father because they are of the same gender (Lancy, 2012) and, ultimately, this would create a higher degree of intergenerational congruence between herself and her mother, than between that of herself and her father (Solaz & Wolff, 2015). This would also mean that there would exist a higher degree of intergenerational congruence between a son and his father (Alvarez & Miles, 2008) than between that son and his mother, because the son would be biased to show a preference for copying the parent of the same gender, too.

But what happens if such model-based biases – in the above case, in the form of a 'copy-the-same-gender' bias – does not manifest solely in the learner's cognition during the acquisition of a cultural trait? What if the mothers and fathers also play a role in choosing which of their children adopt which of their traits and to what degree? It has been found, for instance, that mothers may tend to invest more in their daughters than in their sons (Flouri & Hawkes, 2008) and that they generally spend more time with their daughters (Tucker, McHale, & Crouter, 2003), while fathers spend more time with their sons than they do with their daughters (Lamb & Lewis, 2010).

In the household, then, we could argue that two of Richerson and Boyd's transmission biases (2005) can interact and affect who and what the child learner copies, yet they do so during two stages: acquisition by the learner and onward transmission by the transmitter. First, model-based biases, reflected in the learner's preference to copy models of the same gender (Frazier, Gelman, Kaciroti, Russell, & Lumeng, 2012; Shutts, Banaji, & Spelke, 2010; Taylor, 2013),

will likely influence the learner's choice of whom to copy: if a model of the same gender is present and exhibits a cultural variant A of a trait and another model of the opposite gender is present and exhibits a variant B, the learner will tend to adopt variant A, because of the effects of a 'copy-the-same-gender' bias (though see Henrich & Broesch, 2011 for results indicating the existence of a 'copy-opposite-gender' bias). In parallel, the tendency of the parent to invest in and spend more time with that same-gendered learner would create a larger number of opportunities for that learner to observe that parent/transmitter's behaviour. Thus, the effects of a frequency-based bias will, most likely, be observed in the learner's choices during acquisition, but this would happen due to a model-based bias ('transmit-to-same-gendered-child') affecting the transmitter/parents' choice of whom to teach or to whom they should transmit a cultural trait.

Consequently, we could hypothesise that onward transmission (e.g., when the learners become parents and start transmitting onward cultural traits to their own children) may also be biased, with the transmitters being more likely to choose to transmit one cultural variant over another to new learners depending on, for example, the learner's characteristics (model-based biases), the transmitter's own intention to transmit the most effective or the most memorable variants (content-based biases) and so on. For example, mothers could be biased to display and to teach the behaviours related to housework ('content-based' bias) to their daughters, because they, too, are female ('model-based' bias). Similarly, we could hypothesise that a transmitter would be more likely to transmit onward her taste in clothes to her friends (Napompech & Kuawiriyapan, 2011; Roux & Korchia, 2006), due to their closer proximity ('frequency-based' bias) or due to her and her friends perceiving each other as peers and more similar to one another ('model-based' bias), than to, e.g., other, mere classmates of them. Furthermore, we would expect that the students of a "good" teacher would be more likely to acquire the knowledge transmitted to them by her, than would her peers, due to model-based biases acting on both the students during acquisition ('learn-from-expert' bias) and the teacher herself ('transmit-to-student/novice' bias).

Pathways of cultural transmission

The above everyday examples of social interactions clearly demonstrate another aspect which can impact cultural transmission: the social relationship formed between transmitter and learner. The parent-and-child, friend-and-friend, and teacher-and-student relationships are all

examples where the transmitter and the learner share different characteristics, attributed to them by their respective roles in each case.

Based on the pioneering work of Cavalli-Sforza and Feldman (Cavalli-Sforza, 1986; Cavalli-Sforza & Feldman, 1981), we could argue that all the above different social relationships represent paradigms of different cultural transmission pathways. By borrowing the terms "vertical" and "horizontal" from epidemiology (and adding "oblique"), Cavalli-Sforza and Feldman's research encapsulates all forms of relationships that one individual (or a generation of individuals) can develop with another, through which the transmission of culture can take place (see also Cavalli-Sforza, Feldman, Chen, & Dornbusch, 1982; Guglielmino, Viganotti, Hewlett, & Cavalli-Sforza, 1995).

They proposed that the vertical transmission pathway, much like the biological transmission of genes, entails the communication of cultural information from parent to child, with studies also supporting an indirect vertical pathway from grandparent to grandchild (Bengtson, Copen, Putney, & Silverstein, 2009; Lang & Randall, 2013). Culture can also follow a reverse vertical pathway, from child to parent (Cavalli-Sforza, 1986; Cavalli-Sforza & Feldman, 1981), a horizontal pathway (from one individual or group to another individual or group of the same generation) and an oblique pathway (from an individual or group of a generation to another individual or group of the next generation).

The different transmission pathways can impact cultural evolution in greatly different ways and, as such, they are associated with different traits. For instance, Cavalli-Sforza and Feldman (1981, 1982) have argued that horizontal transmission only guarantees the conservation of cultural information for one generation of learners (the one in which it is transmitted and learned). It is, therefore, associated with the transmission of less complex traits, such as eating behaviours (Baker, Little, & Brownell, 2003; Maximova et al., 2008), and it is adaptive in changing environments (Schönpflug, 2001). In contrast, the vertical transmission pathway ensures the conservation of information for many more generations (Mesoudi & Whiten, 2008b; Tomasello, 2009). It is, therefore, adaptive in stable environments (Schönpflug, 2001) and it is associated with complex traits (Cavalli-Sforza et al., 1982), i.e., ones formed with the accumulation of modifications that each generation of learners adds. That is not to say that a cultural trait will strictly follow only one pathway during transmission. In fact, studies have found that one variant of the same cultural trait can be learned from a parent (vertical transmission) and then, be updated (Henrich & Broesch, 2011; Santoro, Chaves, &

Albuquerque, 2020) or even substituted by horizontal transmission (Reyes-Garcia, Gallois, & Demps, 2016).

Cavalli-Sforza and Feldman's mathematical models have inspired much research (Mesoudi, 2015) that incorporated their ideas into their methods and when deriving their conclusions around cultural evolution (Kobayashi & Aoki, 2012; Lehmann, Wakano, & Aoki, 2013; Mesoudi, 2011a; Nakahashi, 2014; Vogt, 2006). Most of this work has focused on just one aspect of cultural transmission: the context of acquisition by the learner, i.e., they focus on which factors affect the learners' choice of which cultural variants to adopt for themselves (Aunger, 2000; Denton, Ram, Liberman, & Feldman, 2020; Fogarty, Creanza, & Feldman, 2019; Gallois, Lubbers, Hewlett, & Reyes-Garcia, 2018; Hewlett, Fouts, Boyette, & Hewlett, 2011; Laland, 2001; Lew-Levy, Reckin, Lavi, Cristóbal-Azkarate, & Ellis-Davies, 2017; Reyes-Garcia et al., 2016) (figure 1).

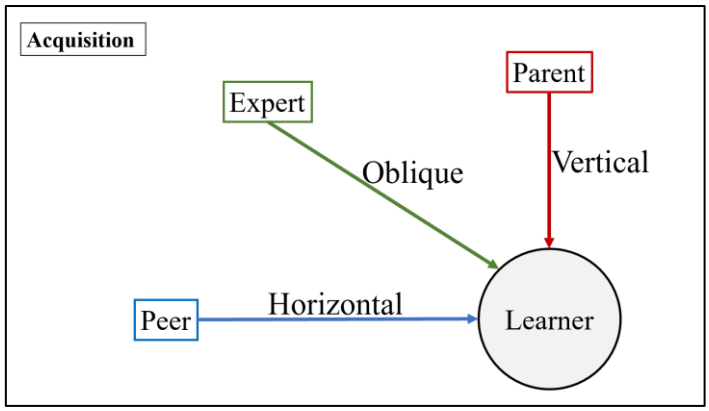

Figure 1: Cavalli-Sforza and Feldman's proposed pathways of cultural transmission as incorporated in previous studies which focused on the context of acquisition by the learner.

However, a cultural trait will not strictly follow only one pathway during transmission. In fact, studies have found that one variant of the same cultural trait can be learned from a parent (vertical transmission) and then, be updated (Henrich & Broesch, 2011; Santoro et al., 2020) or even substituted by horizontal transmission (Reyes-Garcia et al., 2016). It has also been found that one transmission pathway appears to be dominant over the other during different stages in an individual's development (Garfield, Garfield, & Hewlett, 2016; Hewlett, Lamb, Leyendecker, & Schölmerich, 2000). So, an individual will be more likely to adopt the cultural variants of different transmitters depending on her age. For instance, during infancy and early childhood, a child acquires most of her traits vertically, as she is closest to her parents during this stage (Bowlby, 1973). Later in life, with her socialisation with other children outside her household, the acquisition (and transmission) of information from her peers starts through a

horizontal transmission pathway. This will, then, become the dominant pathway (Cavalli-Sforza & Feldman, 1981; Hewlett et al., 2011), with the peers being especially effective transmitters (i.e., it is highly likely that the learners will acquire the transmitted information) during the adolescent years (Brown, Bakken, Ameringer, & Mahon, 2008).

So, a learner could acquire a cultural variant A from a parent and then, substitute it with its competing variant B from a peer later on. For example, an individual could learn from her parents that, before cooking a chicken breast, she should start with washing it with water and salt (chicken cleaning: variant A) and from a friend that she should wash it with lemon juice and olive oil (chicken cleaning: variant B). Model-based biases may predict that this person will be more likely to adopt variant A. However, going beyond model-based biases, we can ask: if that individual is asked to teach someone else how to cook chicken breast and she starts off with teaching them how to clean it, which way will she teach them and why? More generally, when a learner becomes a transmitter, which cultural variants does he/she transmit onward to other learners and which factors impact his/her choice?

The process of onward transmission is, currently, extremely understudied (if at all), thus further impeding our understanding of the cultural transmission process. As a result, these gaps in the literature often lead researchers to contradictory results in relation to cultural transmission biases, such as that individuals prefer to copy a more expert model (Heyes, 2016b; Nagle, 1976) versus, that individuals are more likely to copy a model resembling themselves (Seehagen & Herbert, 2011; Zmyj et al., 2012). Yet, these inconsistencies could be found because the context-dependent biases (Henrich & McElreath, 2003) impacting onward transmission in the above examples are not accounted for. As such, the findings only reflect the (context-dependent) model-based biases imposed on the learners during acquisition and the context-dependent biases affecting their models/transmitters remain unknown. It is the purpose of the current thesis to illustrate – for the first time – that a context-congruence bias impacts both acquisition and onward transmission of a trait by the learner.

Chapter Summaries

In summary, several gaps have been identified in the literature. The chapters that follow consist of studies that were designed to address these and advance our understanding of cultural evolution.

Chapter 2 - Effects of verbal instruction vs modelling on imitation and overimitation

In this chapter we investigate (i) the developmental changes in overimitative behaviour and (ii) the distinct effects of language as a mode of transmission on cumulative culture, by implementing an experimental design with multiple variables. To address the first, we examine the (over)imitative tendencies of young adults (18 to 32 years old) and six- to eight-year-old children. As such, the study provides data on the overimitative tendencies of participants of different age groups than most of the existing studies do. If, in fact, there is a developmental increase in the tendency to overimitate, we would expect that the children in this age group would copy and transmit causally irrelevant actions along their transmission chains, though at lower degrees than the adults in the study. By implementing a two-way action approach design (McGuigan & Graham, 2010; McGuigan & Whiten, 2009; McGuigan et al., 2007), this study also tests the effects of the two transmission modes (language vs. modelling) on the likelihood that participants will introduce innovations along their chains (by, for example, swapping the observed causally relevant action of sliding the door of the box to the side to open with the unobserved causally relevant action of lifting the door upwards to open). If overimitation increases with age, we would expect children to be less inclined to copy their transmitters' causally irrelevant actions (in either condition) or deviate more from their input than the adults, by introducing more innovations to achieve the extraction of the reward from the box.

To address the second, we tested and explicitly compared the effects of language (in the form of verbal instructions exclusively, without any other form of input, such as visual) versus modelling (i.e., visual demonstration without any other form of input, such as audio) on the likelihood that participants will (over)imitate. Though we expected a loss of causally irrelevant actions in general, as was the case in previous studies, we expected that this loss would be more pronounced in the verbal instructions condition than in the demonstration condition. So, overimitation would be more evident in the demonstration condition and, by extension, the accumulation of efficiency (i.e., later generations completing the task with the usage of fewer causally relevant actions than the first) would be more pronounced in the verbal instructions condition than in the demonstration condition. This study, thus, investigates how the exclusive use of language as a mode of transmission in adult versus in child chains influences the CCE of efficiency (i.e., the increasing loss of causally irrelevant actions along generations).

So, Chapter 2 focuses primarily on investigating the effects of three variables – namely transmission mode (verbal instructions versus visual demonstration), age group (adults versus children), and action causal relevance (action is relevant to obtaining the reward or it is irrelevant) – and their interactions on three dependent variables: action retention (binary variable indicating whether an action present in a participant's input was also present in their output), action innovation (binary variable indicating whether a participant produced an action that had not been present in their input) and the CCE of efficiency (a decrease in the number of irrelevant actions in participants' outputs over generations).

The analysis focused on the extent to which actions were (over)imitated by participants, how much innovation participants introduced and how the efficiency of action sequences cumulatively evolved over the three generations.

Though both age groups overimitated, the results are in contrast with the previously proposed developmental increase in overimitation (Berl & Hewlett, 2015; McGuigan et al., 2011, 2007; McGuigan & Whiten, 2009; Moraru, Gomez, & McGuigan, 2016). Overall, adults did not overimitate significantly more than children did and, especially when the sequence was transmitted via verbal instructions, children overimitated significantly more than adults did. This has important implications about the discrepancies currently found in the literature. The results suggest that the mode of transmission (language versus demonstration) could be what produces the opposing findings in adults' and children's overimitation, with children producing more of the causally-irrelevant actions when they receive verbal instructions about them, and adults producing more causally irrelevant actions when they see them demonstrated.

The results also suggest that efficiency had cumulatively evolved to a greater extent along the adult chains overall. The mode of transmission indicated that, in adults, cumulative increases in efficiency are facilitated by language, with causally irrelevant actions being omitted from the adults' output in the verbal instructions condition faster and to a higher degree than in the demonstration condition. On the other hand, in the child chains, there was more loss of causally irrelevant actions in the demonstration condition.

So, with language facilitating more overimitation in children than demonstration, this leads to a higher degree of conservation of the transmitted actions in the child chains than in the adult chains. This happens exactly because efficiency does not accumulate as much in children when the transmission of behaviour is carried out linguistically. Instead, children are more inclined to learn and transmit with high fidelity the cultural product that they receive, even if they

introduce innovations to it. And, with CCE being defined as the high-fidelity copying of the transmitted information and the addition of changes by each generation of learners, which results in the formation of complex and sophisticated products (Caldwell & Millen, 2008a; Henrich et al., 2016; Mesoudi & Thornton, 2018), we could argue that language acts as a conservative transmission modality that promotes the evolution of cumulative culture in children, but not in adults.

Chapter 3 - Context of learning behaviours and the model biases on cultural transmission

To investigate the effects of a context-congruence bias on cultural transmission, we implemented a novel experimental design, which allowed us to examine onward transmission by the learners. In this, participants were taught two different cultural variants of the same cultural trait from two different transmitters (context of acquisition): variant E, which was transmitted by an expert, i.e., the experimenter, and variant P, which was transmitted by a peer, who was a confederate. The two different transmitters (expert and peer) represented two different transmission pathways (vertical and horizontal respectively). After the participant learned both of the variants, he/she was asked to transmit onward one of them to a second confederate, who posed as another participant. To half of our participants, the second confederate was presented as a novice, which provided the participant the higher status of an expert, and to the other half as their peer (context of onward transmission). So, in the context of onward transmission, the participants could choose to transmit the vertically acquired variant E, or the horizontally acquired variant P. Figure 2 below presents this design.

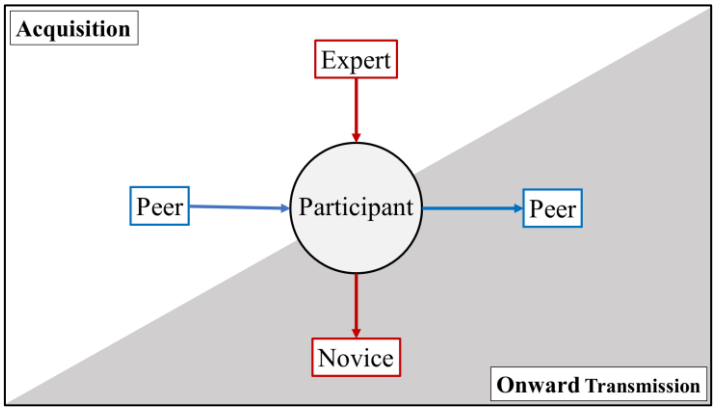

Figure 2: The experimental design used in Chapter 2. Here, the context of acquisition (learn from expert and peer) is presented in the white background and the context of onward transmission (transmit to novice versus transmit to peer) is presented in the grey background.

Apart from the expected model-based bias, whereby the expert variant would be transmitted overall more often than the peer variant, we hypothesised that a context-congruence bias would impact the participants' choice of which variant to transmit, making variant P more likely to be transmitted to the peer confederate and variant E more likely to be transmitted to the novice confederate.

Both of the above hypotheses were supported. First, variant E was preferred over variant P during onward transmission by the learner overall. Nonetheless, in the condition of participant-to-peer transmission participants chose to transmit variant P significantly more often than variant E.

We attribute this finding to the context-congruence bias – the first factor found to link the contexts of acquisition by the learner and onward transmission when that learner becomes a transmitter. According to this, the learners' choice of what variants to transmit onward is impacted by the relationship they had with the transmitter during acquisition (e.g., peer-to-learner) and by their relationship with the new learner when they themselves become transmitters (e.g., transmitter-to-peer). By extension, when a cultural variant becomes associated with horizontal (peer-to-peer) transmission, it will most likely continue to follow that same pathway, and a cultural variant associated with vertical transmission (e.g., parent-to-child) will continue to follow a vertical pathway. The context-congruence bias, then, can allow us to predict for how long cultural traits will survive in a population.

Chapter 4 - Understanding Cultural Information Flow: A Qualitative study of a small social group

The two experimental studies of Chapters 2 and 3 provide empirical evidence that tests the assumptions of previous mathematical models (Boyd & Richerson, 1985; Cavalli-Sforza & Feldman, 1981) and contribute to the experimental methodologies (e.g., of Horner & Whiten, 2005; McGuigan & Graham, 2010; McGuigan et al., 2011a) used to study cultural evolution by pointing out further factors that need to be considered (such as the developmental changes in the function of language during cultural transmission).

Nevertheless, cultural transmission is a complex process, and it is not enough to focus only on its more quantitative aspects, such as the frequency with which a cultural variant is transmitted, or which transmitter's cultural variant is more likely to persist. Laboratory experiments implementing the transmission of simple tasks in artificial settings do allow us to control and

to manipulate variables – which is impossible to do in, e.g., naturalistic studies – but, when they are used in conjunction with other methods (Mesoudi, Whiten, & Laland, 2006), "a better understanding of cultural phenomena can be attained than when a single method is used alone" (Mesoudi & Whiten, 2008a, p. 3499).

According to Mesoudi (2007), the solution to addressing both the experimental and the qualitative methods' trade-offs is to treat them as complementary. Therefore, to complement the first two studies of the thesis, which comprise of quantitative, experimental methods, we introduce a third, qualitative study in the fourth chapter, which explores how cultural information flows in a real-world paradigm. The mathematical model of the cultural transmission pathways (Cavalli-Sforza & Feldman, 1981) can be a very good fit for populations, or a controlled experiment such as that of the second study of this thesis. It is a clear, rigid model and, as such, it has many benefits for quantitative analyses. However, it cannot be applied to real-world paradigms. For instance, according to the mathematical model, a mother would form a 'vertical' relationship with her child and the cultural information she transmits would follow a vertical pathway. That mother, though, can also be the learner of information transmitted to her by her child ('reverse vertical' pathway), she can be the transmitter to an older of her children who, then, transmits onward horizontally the behaviour to the younger child, she can be the 'horizontal' learner and transmitter of information by her spouse and/or her friends and so on, and every cultural trait she transmits may assume different forms depending on the contexts of acquisition and onward transmission, on the properties of the trait etc. So, cultural information flows in much richer and complex ways in real world social networks than a rigid model could encapsulate, and we need to capture this richness. It is important but not enough to investigate cultural transmission though the construction of mathematical models or laboratory experiments that simplify and control the process. Thus, instead of just focusing on the population level, we need to explore cultural transmission at the level of the individual, the family, and their social environment. In addition to the above, qualitative data can provide insights on why individuals behave in the way that they do and serve as the base to generate new hypotheses that can be tested quantitatively.

Our data for Chapter 4 comprised of both one-on-one semi-structured interviews with my parents, my three siblings and my maternal grandmother, as well as observational logs. Semi-structured interviews were also conducted with their peers, three of whom also constituted grandmother, mother, and granddaughter, and two others were mother and daughter. The rest were individual friends my family members had made over the years. This specific sample

allows the in-depth examination of how cultural information flows within two different three-generational families and their peers. By thematically analysing the interview data, we extracted three main themes – namely, individual learning, horizontal transmission, and vertical transmission These consisted of categories that have previously been the focus of discussion around cultural transmission and/or cultural evolution. Thus, this study provides new, qualitative perspectives to these discussions.

Chapter 5 - General Discussion

In a concluding fifth chapter, I will summarise the findings of the three studies of this thesis and their implications for cultural transmission and the theory of cultural evolution. In particular, I will discuss how language may shape the dual engines (i.e., imitation and innovation) of cultural evolution, how the context-congruence bias can affect cultural transmission and, therefore, aid our understanding of cultural evolution, and I will argue for the importance of adopting a unifying framework to study cultural evolution.

In addition, I will discuss the methodological challenges we encountered, as well as how these have been dealt with, or considered. I will also discuss new opportunities for research that can arise from dealing with the challenges we encountered, such as the controlling confounding variables in order to make more reliable cross-cultural comparisons.

Finally, I will make recommendations for future research, based on the findings of my thesis and previous work that has informed it. These will be focused on encouraging the examination of overimitation during both acquisition and onward transmission (e.g., whether the causally irrelevant elements of behaviours learners retain during acquisition are transmitted to other learners during onward transmission) and on assessing the effectiveness of particular transmitters (such as that of the mother in a social network) versus that of others (such as that of the father).

Chapter 2

Effects of verbal instruction vs. modelling on imitation and overimitation

Abstract

Human culture is the result of a unique cumulative evolutionary process. The social transmission mechanisms underlying this process are still not fully understood. In particular, the role of language – another unique human behaviour – in social transmission is under-explored. In this first direct, systematic comparison of demonstration vs language-based social learning, we measured the transmission fidelity and cumulative improvement of an action sequence whose objective was to extract a reward from a box. Participants were organised in transmission chains, and each of them either watched a model demonstrate an action sequence or listened to verbal instructions to produce the action sequence. In order to explore imitation and overimitation, the sequences included actions that were causally relevant or irrelevant, respectively, to extracting the reward. We explored these effects in transmission adults and in 6 to 8-year-old children. Overall, we found more copying under demonstration than verbal instruction, and of causally relevant than irrelevant actions. However, children (but not adults) copied more causally irrelevant actions under verbal instruction, but more causally relevant actions under demonstration. Cumulative cultural evolution produces sophisticated, complex behaviour whose function may not be obvious. By promoting the retention of behaviour even when its function is not understood, specifically in children, language may play a supportive role in cumulative cultural evolution.

1 Introduction and Literature Review

Social transmission and cumulative cultural evolution

Human culture – our complex, refined behaviours, technologies, institutions, ideas etc – is the unique product of cumulative cultural evolution (Boyd & Richerson, 1996). Tomasello (1999) termed the mechanism for cumulative cultural evolution the 'ratchet effect': modifications to a cultural trait can be retained and beneficial changes can accumulate to yield products of such sophistication as no single individual or generation could accomplish on their own (Tomasello et al., 1993). Legare and colleagues emphasise the 'dual engines' of cumulative transmission, namely imitation and innovation. The former allows the transmission of a vast array of cultural traits from generation to generation and eliminates the costs of individual learning by trial and error, and it is the focus of this chapter; the later enables cultural adaptation to new environments (Legare & Nielsen, 2015; Legare & Harris, 2016). In order to support cumulative cultural evolution, transmission of information between individuals must have a high degree of fidelity (Tomasello, 1994, 1999; Tennie et al., 2009). Imitation, a type of social learning that focuses on faithfully copying the actions observed rather than their outcomes, is crucial for faithful transmission (Tomasello, 1990; Whiten & Ham, 1992; Meltzoff, 2007; Tennie et al., 2009) as it allows learners to acquire skills even if they do not fully understand the goal of each action (Horner & Whiten, 2005; Gergely & Csibra, 2006; Tamariz, 2019).

The importance of language and demonstration in social transmission

Language, a uniquely human behaviour that mediates communication and supports cooperation and collaboration (Tomasello, 2006) and teaching (Laland, 2017), can boost the transmission fidelity of knowledge, attitudes, beliefs and values beyond what can be learned through the observation of actions and outcomes. In spite of this, the vast majority of social transmission studies involve observational learning, in which a demonstrator performs an action for an observer, who then goes on to attempt it. This approach suits developmental as well as cross-species comparative goals, but it neglects the role of language as a potential mainstay of human cumulative cultural evolution.

Several recent studies of social learning have incorporated verbal instruction to their designs *in addition to* demonstration. In one condition of Dean et al.'s (2012) study, 3 and 4 year-old children learned how to extract a reward from a puzzle box by observing other children. Some of the demonstrators spontaneously provided instructions, and learners who received these

instructions significantly outperformed those who did not. Dean et al. (2012), therefore, linked language (among other factors) and cumulative improvement. Zwirner and Thornton's (2015) participants had to construct baskets out of everyday materials that could carry as much rice as possible. The authors found that teaching was not essential for cumulative improvement, although its presence resulted in more robust baskets than when they only observed others' actions (imitation) or only observed the finished product (emulation). Caldwell and Millen (2009) evaluated the contribution of different types of social learning to cumulative improvement using a task in which participants had to make paper aeroplanes that would fly as far as possible. They systematically manipulated whether participants could do imitation, emulation and receive teaching, which included a verbal component, and found that performance improved in all conditions to similar extents. Prior familiarity with the task, however, may have confounded the results. Action familiarity may bias cultural transmission, but it is not clear how. Meltzoff (1988a, 1988b) found that 14-month-olds tended to reproduce novel actions, but in Reader et al.'s studies (2007), participants tended to follow a familiar route over a novel one, even if it was costlier.

A group of studies have examined the effects of verbal instruction on social transmission using stone-tool manufacturing tasks, with conflicting results. Putt et al. (2014) had participants learn how to make bifaces and found that adding verbal instructions to demonstration of an action sequence increased copying fidelity, as it increased the probability that novice participants would reproduce the instructor's exact actions. However, language made no significant difference in terms of skill, i.e., how well participants learned the target behaviour. In the demonstration-only group, individual actions were more efficient. The conclusion that language does not necessarily enhance transmission is in line with a similar study by Ohnuma et al. (1997). Here, participants' production of Levallois stone tools did not differ between a demonstration-plus-verbal-instruction and a demonstration-only group. In contrast with those studies, in Morgan et al.'s (2015) comparison of five transmission mode conditions (involving demonstration, gestural communication and verbal communication) in a flint flake manufacture task, participants in the 'verbal teaching' condition performed significantly better than in most other conditions, and slightly better than participants in the 'gestural teaching' condition**.**

In these studies, verbal transmission was never tested in isolation. The verbal or teaching conditions often involved face to face interaction, during which participants engaged in both verbal and gestural interaction (Dean et al., 2012; Caldwell & Millen, 2009; Zwirner &

Thornton, 2015). Morgan et al. (2015) included distinct gestural and verbal teaching conditions; however, in both cases verbal input was provided in addition to observation. The effects of verbal instruction and observational learning on social transmission have, to our knowledge, never been directly compared.

The skills transmitted in social learning studies typically include causally relevant actions, which are necessary to the completion of the task, and causally irrelevant actions, which are not required for task completion. Comparative studies show that humans do "blanket copying", i.e., they copy the actions they see no matter whether those are causally relevant ('imitation') or irrelevant ('overimitation', Nielsen, 2006; Lyons et al., 2007, see Hoehl et al., 2019 for recent review) and irrespective of whether they have information about their causality or not (Whiten et al., 2009). Other primates, in contrast, tend to omit actions known to be causally irrelevant from their output (Horner & Whiten, 2005). Cross-cultural studies reveal that overimitation is present across a variety of world cultures (Nielsen & Tomaselli, 2010; Nielsen et al., 2014; for an exception in the Aka children, see also Berl & Hewlett, 2015; Clegg & Legare, 2016). As an enabler of faithful action transmission unbiased by causal relevance or efficiency, overimitation plays a key role in cumulative cultural evolution (Legare & Nielsen, 2015; Tomasello, 2016; Nielsen, 2018; Tamariz, 2019).

Overimitation does not always have the same degree of fidelity. Rather, children are capable of doing flexible imitation (Clegg & Legare, 2017) according to the nature of the task. Causally opaque actions presented as conventional, or 'social 'rituals' (Hermann et al., 2013; Legare et al., 2015; Clegg & Legare, 2016) and actions that are 'playful' (Nielsen et al., 2012) are copied with higher fidelity than instrumental actions that achieve a functional goal. This difference seems to decrease with age, as older children copy conventional and instrumental causally irrelevant actions with similar fidelity (Moraru et al., 2016).

Children are high fidelity imitators and overimitators (Nagell et al., 1993; Horner & Whiten, 2005; Call et al., 2005; Tennie et al., 2006; McGuigan et al., 2007; McGuigan & Whiten, 2009; McGuigan et al., 2011; Flynn, 2008; Flynn et al., 2012; Haun et al., 2014), as are adults (McGuigan, 2012, Whiten et al., 2016). The tendency to overimitate seems to increase with age, as older children copy causally irrelevant actions more than younger children (McGuigan et al., 2007) and adults more than children (McGuigan et al., 2011; McGuigan, 2012).

A common experimental paradigm used to explore how social learning supports cultural accumulation involves transmission chains in which the actions reproduced by a participant are

shown to the next participant in the chain. This paradigm amplifies the effects of transmission biases (Kirby et al., 2008). Studies with children show that, along the chain, innovations are introduced, and causally irrelevant actions are omitted to a higher extent than causally relevant ones, which results in a cumulative increase in efficiency or adaptiveness in most cases (Flynn, 2008; McGuigan & Graham, 2010; McGuigan, 2012; Tennie et al., 2014; McGuigan et al., 2017).

Objectives and Hypotheses

We designed a study to explore the role of two transmission modes – verbal instructions versus demonstration – by children and adults on the social transmission of relevant and irrelevant actions and the cumulative improvement of efficiency. The explicit comparison between the two modes of transmission has not been the focus of previous studies and, as such, this study will provide the first results in these respects. We used an existing experimental task and apparatus in which participants had to extract a reward from a box. In order to explore this effect, half of the actions in our sequences were novel or unfamiliar to our participants (i.e., they might not have performed them or witnessed their performance prior to their participation in these studies) as in most of the studies mentioned above, and the other half were familiar. Half of the actions were relevant, and the other half, irrelevant. Given the attested differences in imitation and overimitation across ages, we tested 6-to-8-year-old children, who had finished either the first or second grade of primary school (for other studies that have grouped together this exact age range within conditions see Kumpfer et al., 2002; Patil et al., 2014; Neely et al., 2016 etc.) and adults. And we arranged our participants in transmission chains to test retention and innovation of actions as well as cumulative improvement in efficiency.

We expect that the mode of transmission (verbal instructions versus demonstration) will affect action retention (actions present in both the input and the output of participants). Specifically, as most of the literature implements demonstration as a transmission mode and only uses verbal instructions to compliment it, we hypothesise that (1) participants allocated in the Demonstration condition will retain (in their output) significantly more of the previous generation's actions (input) than the participants allocated in the Verbal instructions condition. So, we believe that the participants allocated in the Verbal instructions condition will be more likely to modify/omit some of the actions in their input. We also predict that (2) causally Relevant actions will be copied more than Irrelevant actions across conditions, as in previous studies. We expect to find (3) overimitation (copying causally Irrelevant actions) in both age

conditions, but more so in Adults – who copy actions with higher fidelity than Children, based on the majority of previous studies – across conditions.

By extension, we hypothesise that (4) more innovations (i.e., actions absent from the participants' input but present in their output; see sections "coding" below) will be produced by Children than by Adults and that (5) most of the innovations produced will be causally Relevant. Moreover, we expect that (6) participants in the Verbal instructions condition will produce significantly more innovations than the participants in the Demonstration condition.

Finally, regarding cumulative improvement, we hypothesise (7) an improvement of efficiency along the transmission chains, and therefore we predict fewer irrelevant actions at later generations in the transmission chains across conditions. We expect (8) a steeper decrease in the proportion of irrelevant actions over generations in our Child than in our Adult chains (as adults are better overimitators) and (9) in the Verbal instructions than in the Demonstration condition (as participants in the latter are expected to produce more of the actions in their input). Given the conflicting results in the literature, we do not have a prediction about copying novel and familiar actions.

2 Methods

The study obtained ethical approval from Heriot-Watt University's School of Social Sciences ethical committee, and it was pre-registered with the Open Science Foundation.

2.1 Participants

Seventy adults (31 female; age range 19-32 years, M=22.94 years, SD=3.11 years) were recruited and tested in public libraries and cafes in Cyprus. Sixty of the participants were assigned to twenty chains (three participants per chain) so that the mean age of every chain was approximately equal, with all chains including male and female participants and the male-female ratio being similar across chains and conditions. The remaining ten participants formed the adult control group. No compensation was given to the adult participants.

Seventy children (30 female; age range 6-8, M=6.72, SD=0.76) were recruited in Cyprus in summer schools, playgrounds and among the experimenter's personal network. Sixty of the children were assigned to twenty chains (three participants per chain) so that the mean age of every chain was approximately equal, and the male-female ratio was similar across chains and

conditions. The remaining ten participants formed the child control group. The children received stickers as compensation for their participation.

Two additional participants were the 'seeds' used to record the stimuli. They were a male adult and a male 9-year old, both native Greek Cypriot speakers.

No data was excluded, as every participant completed the task successfully.

2.2 Materials

2.2.1 Apparatus

The apparatus presented to all participants was an adaptation of the opaque box used in previous studies with both children and adults (McGuigan et al., 2007; McGuigan & Whiten, 2009; McGuigan & Graham, 2010). For this study, the bolts in the upper part of the original box were not used (Fig.1).

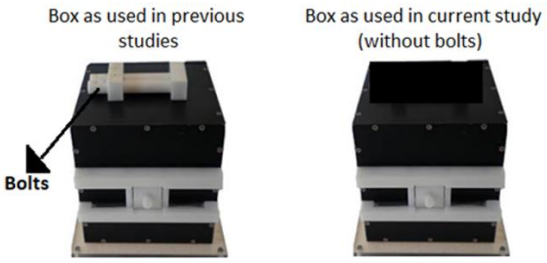

Figure 1. The box used in the experiment.

A reward was housed in a tube inside the box. The reward could not be retrieved using a finger; in order to extract it, participants could use a rod with a magnet attached to one end (which was covered in red tape), and a blue Velcro on the other end. The reward inside the box was a metal ball wrapped in Velcro, so it was possible to retrieve it by using either the red or the blue end of the rod.

2.3 Design

We used a linear transmission chain design in which the participants were organised into chains of three generations (each participant represents one generation, Fig. 2). We had a total of 40 chains: 20 chains of children and 20 of adults. In each chain, the input to generations 1, 2 and 3 was the (video or audio) recorded output of the preceding generation; generation 1 was exposed to the output of the seed (generation 0). By the third generation, a product was

produced which was the result of the acquisition of behaviour from a participant (generation 2) who had acquired the behaviour from another participant (generation 1). By the third generation, then, we assumed that the seed's effect on the chain would be minimised enough to examine the transmission of the actions within each of our chains. The large number of our chains would, also, allow us to make quantifiable comparisons between them.

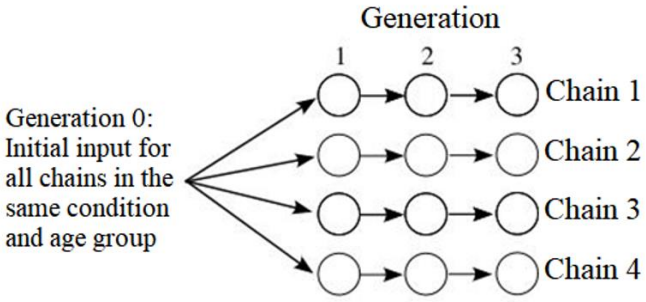

Figure 2. Linear transmission chain structure.

Aside from participant age and the position of participants in the transmission chain (or 'generation'), we manipulated the causal relevance and familiarity of the actions and the social learning condition (demonstration or verbal instruction) (see Procedure below).

2.4 Procedure

2.4.1 Initial stimuli

We manipulated two independent variables related to the actions. Causal relevance: Half of the actions were causally relevant, and therefore were necessary to retrieve the reward, and the other half were causally irrelevant -unnecessary to retrieve the reward. Familiarity was judged a priori as the likelihood that the participants had seen or done an action before, and a posteriori as the likelihood that they would produce an action spontaneously, in other words, we generated unfamiliar actions that we thought were novel to participants, and we expected that a naive participant would not produce those actions if asked to interact with the box.

The first participant in each chain (the 'seed') was taught two different sequences of four actions (Table 1). These were the same for the adult and the child seed and they consisted of two causally relevant actions (CR), which were necessary for retrieving the reward, and six causally irrelevant (CI) actions, that were not necessary for retrieval. Also, two of the actions were familiar (F) and two were novel (N). The CR actions are ones present in previous studies

using the same apparatus (McGuigan et al. 2007; 2010; 2011). The CI actions are made up specifically for the purposes of this study: they are actions easily performed by both adults and children and simple enough for them to remember. The CI actions also need approximately the same amount of time to be performed as the CR ones, thus balancing the time of participant exposure to both CI and CR actions. Following the two-action approach (Dawson & Foss, 1965; Whiten et al., 2016; McGuigan et al., 2007, 2010, 2011) a different sequence of actions was the input for half of the chains in each condition, as follows:

Table 1. Action sequences performed (in the demonstration condition) or verbalised (in the verbal instruction condition) by the seeds.

	Action Performed	**Action Verbalisation**
Sequence 1: **for 10 chains of children** **and 10 chains of adults**	Tap three times on the side of the box with the rod (CI, F)	"I tap three times on the side of the box with the rod"
	Swipe rod on the hand three times (CI, N)	"I swipe the rod on my hand three times"
	Lift door with hand (CR, F)	"I lift door with my hand"
	Insert (red) magnetic side of rod in door to extract the reward (CR, N)	"I put the red side of the rod in the door to get the ball"
Sequence 2: **for the other 10 chains of children** **and the other 10 chains of adults**	Pass the rod from hand to hand three times (CI, N)	"I pass the rod from one hand to the other three times"
	Swipe the rod on the side of the box three times (CI, F)	"I swipe the rod on the side of the box up and down three times"
	Slide door with hand (CR, F)	"I slide the door with my hand to the side"
	Insert (blue) Velcro side of rod in door to extract the reward (CR, N)	"I put the blue side of the rod in the door to get the ball"

The two seed participants were trained by the experimenter to produce the initial action sequences (see Table 1), after obtaining informed consent from the adult and the child's parents. Their live demonstrations (for the Demonstration condition) were video recorded, and the spoken descriptions of their actions (for the Verbal Instruction condition) were audio recorded in separate sessions. We used recorded information, in line with other studies in the same area (McGuigan et al., 2007; Wood et al., 2012) for practical reasons.

2.4.2 Social learning conditions

Informed consent was obtained from the remaining adult participants and, in the case of children, from their parents. Participants were allocated to one of the following three conditions:

Demonstration condition: Each participant was offered a seat in front of a laptop and the box (which they could see right next to the laptop). The experimenter told them: “Inside the box there is a ball. The goal is to take the ball out of the box. Before you try, I will show you a video of another participant who took the ball out. The video will play three times. Then, you can try, too”. The video-recorded actions performed by the previous participant in the chain (or, for generation 1, by the seed) were presented three times on the laptop with the volume muted. Following the task demonstrations, the experimenter invited the participant to "have a go". Their actions were video-recorded. Participants were allowed to interact with the box for a maximum of five minutes, or until they retrieved the reward successfully, if this was less than five minutes, or until they became frustrated or refused to continue. All participants were successful in retrieving the reward within time allocated. While the participants were carrying out the task, the experimenter did not interfere.

Verbal Instruction condition: Each participant was offered a seat in front of the box and the laptop, and they were told: “Inside the box there is a ball. The goal is to take the ball out of the box. Before you try, I will play for you the [voice] recording of another participant who took the ball out. The recording will play three times. Then, you can try, too”. The recorded verbal instructions from the previous participant in the chain (or, for generation 1, by the seed) were then played three times on a laptop computer (mp3 player). Following the task demonstrations, the experimenter invited the participant to "have a go", and his or her actions were video-recorded. After the participant finished the task, the experimenter gave the following instructions: “I will play for you a video of yourself on my laptop, and I want you to watch carefully what you do. Every few seconds, I will pause it. Each time I pause the video, I would like you to tell me what you do in it”. To make sure the participant understood the voice-recording procedure, the experimenter asked them if they had any questions. After making sure her instructions were clear, she played for each participant their video and she paused it after every action. She then brought the microphone close to the participant, who described their actions as they saw it. All participants were able to describe their sequence action by action. The experimenter did not guide them as to in which format they should give their descriptions

(some of them took a first-person perspective and others a second-person perspective). Their descriptions of their actions were audio-recorded, and they were used as the audio input for the next participant in the chain. Participants were allowed to interact with the box undisturbed until they retrieved the reward successfully, or after five minutes, as above.

Control condition: The experimenter invited each participant to interact with the box by saying: "There is a reward in this box. Can you take it out?". They were allowed to interact with the box undisturbed until they retrieved the reward successfully, or after five minutes, or if they became frustrated or refused to continue (all participants were successful). They were video-recorded while they interacted with the box.

In all three conditions, after each participant finished the task, they were thanked and led to a different room to be debriefed. In addition, they were asked, for some of the actions they performed, why they performed it the way they did: “Why did you do x?”.

2.5 Coding

The video recording of participants in the Demonstration and the Verbal Instruction conditions were coded by the experimenter. One more naïve observer – co-author MT – coded random samples (10%) of the data for reliability regarding the variables below. Cohen's κ (Landis & Koch, 1977) revealed near-perfect inter-coder agreement, $\kappa=.838$ ($p < .000$), 95% CI (0.799, 0.877). For each individual action performed by a participant, three (related) dependent variables were coded:

(i) **Action retention**: A binary variable indicating whether an action present in a participant’s input was also present in their output. In other words, whether an action produced by the previous participant (or by the seed in the case of generation 1) was reproduced by the participant. Actions were coded as retained as long as they were copies of an observed action, and this included exact replicas, slight modifications, and variations in the number of times an action is produced (e.g., swiping the rod on the hand 4 rather than 3 times, inserting the observed side of the rod in the door three times).

(ii) **Action innovation**: A binary variable indicating whether an action produced by a participant was novel, i.e., had not been present in the participant’s input. Examples include throwing the rod in the air and catching it and tapping on the box with the hands (see Appendix A for a full list of actions).

(iii) **Cumulative improvement in efficiency**: A specific decrease over generations in the number of irrelevant actions produced by participants, indicating a cumulative increase in efficiency. (This is different from action retention and innovation. Here, we consider the proportion of irrelevant actions out of all the actions produced by participants, regardless of whether they are copied or innovated). Cumulative improvement in efficiency is measured as such and not timewise (which would be a more common measure for efficiency), as participants who use only causally relevant actions sometimes require longer to complete the task than those who use causally irrelevant ones, too. This might be due to memory constraints, doubts/thoughts of what to do and so on. The proportion of irrelevant actions out of all the actions produced is, therefore, the most objective measure of cumulative increase in efficiency for the purposes of this study.

The actions produced by participants in the control condition were coded as causally relevant if they contributed to extracting the reward or as causally irrelevant if they did not contribute. (Appendix B lists all actions performed by the control group). All participants in the control group were successful in retrieving the reward from the box. Apart from some attempts to retrieve the reward by inserting their finger in the door, there were no causally irrelevant actions.

2.6 Analysis

(i) Action retention as the outcome variable: To test hypotheses 1 (more retention in Demonstration than Verbal Instructions), 2 (more causally Relevant actions retained than Irrelevant ones) and 3 (more retention of causally Irrelevant actions by Adults than by Children) (see Introduction) we used R (R Core Team, 2012) to construct a generalised linear mixed effects model (binomial family). The model was fit using glmer from the lme4 package (Bates, Maechler, & Bolker, 2012; Bates et al., 2015) and the bobyqa optimiser. As per Winter and Weiling's (2016) method, retention (whether an action was present in the output or not) was tested as the outcome variable separately; our fixed effects were transmission mode (verbal instructions/demonstration), participant age (adult/child) and action relevance (causally relevant/irrelevant), and we included random intercepts for participant and action. We also included the interactions of our fixed effects (as the model containing them was significantly better than the one which did not; $\chi2 = 13.67$, $df = 4$, $p<0.01$). The full model (formula: *RETENTION ~ Causal Relevance * Transmission Mode * Age + (1 | Participant) + (1 |*

Action)) was tested against the null model, which contained only the random effects (formula: *RETENTION ~ (1 | Participant) + (1 | Action)*), using the anova() function.

(ii) **Action innovation as the outcome variable:** To test hypotheses 4 (more innovations produced by Children than by Adults), 5 (more causally Relevant innovations produced than causally Irrelevant ones) and 6 (more innovations produced in the Verbal instructions than in the Demonstration condition), we used Chi-squared tests of independence to test the effects of participant age (adult/child), action relevance (causally relevant/irrelevant) and transmission mode (verbal instructions/demonstration) on Innovation.

(iii) Cumulative improvement in efficiency as the outcome variable: To test hypotheses 7 (cumulative improvement will be observed across conditions), 8 (Child chains will have a steeper increase in cumulative improvement over generations than Adults ones) and 9 (there will be a steeper increase in cumulative improvement in the Verbal instructions than in the Demonstration condition), we used R (R Core Team, 2012) to construct a generalised linear mixed effects model (binomial family). The model was fit using glmer from the lme4 package (Bates, Maechler, & Bolker, 2012; Bates et al., 2015) and the bobyqa optimiser. As per Winter and Weiling's (2016) method, cumulative improvement was tested as the outcome variable separately; our fixed effects were transmission mode (verbal instructions/demonstration), participant age (adult/child) and generation (ordinal variable: generation 1, generation 2 and generation 3), and we included a random intercept for chain. We also included the interactions of our fixed effects (as the model containing them was significantly better than the one which did not; $\chi 2=13.69$, df=7, $p<0.06$). The full model (formula: *CUMULATIVE IMPROVEMENT ~ Generation * Transmission Mode * Age + (1 | Chain)*) was tested against the null model, which contained only the random effect (formula: *CUMULATIVE IMPROVEMENT ~ (1 | Chain)*), using the anova() function.

3 Results

Data coding revealed that participants in the control condition spontaneously performed the actions which we had previously coded as "unfamiliar". This means that our criterion to distinguish familiar and unfamiliar actions did not hold. As a consequence, familiarity was not considered further. Table 2 shows, for each generation, the number of action tokens in participants' input, which can be broken down into number retained plus number lost. It also shows the number of actions produced by participants which equals the sum of actions retained

plus actions innovated. (The output of generation 3 was not actually *used* as input, as our chains were 3 generations long.)

Table 2. the fate of actions by generation.

Generat.	In input	Retained	Lost	Innovated	In output
G1	160	107	53	27	134
G2	133	77	56	42	119
G3	119	88	31	20	(108)
TOTAL	412	272	140	89	361

3.1 Action retention

Of the total number of actions present in the participants' input at each generation, 67%, 58% and 74%, respectively, were also present in their output, i.e., were retained (Table 2). The actions in the input at each generation, including generation 4, significantly decreased over generations ($\chi^2(3)=12.79$, $p<0.01$. (Not including generation 4: $\chi^2(2)=6.91$, $p<0.05$).

In order to establish how transmission condition, action relevance and participant age affected the probability that an action present in the input was also present in the output, we considered only the subset of actions at each generation that had been present in participants' input, i.e., all actions produced excluding innovations.

The full model – containing all three fixed effects (transmission mode, participant age, action causal relevance) and their interactions – was significantly better than the null model ($\chi2=18.77$, $df=7$, $p<0.01$). Table 3 below summarises our full model.

Table 3. Summary of the model including transmission mode, participant age and action relevance as fixed effects, and random intercepts for participant and action.

Model: Causal Relevance * Transmission Mode * Age + (1 | Participant) + (1 | Action)				
	Estimate	**SE**	***z*-value**	***p*-value**
Relevance (Relevant)	1.67	0.81	2.06	<0.05*
Transmission mode (Demonstration)	1.09	0.73	1.49	>0.1
Age (Children)	1.56	0.69	2.26	<0.05*
Relevance (Relevant) x Transmission mode (Demonstration)	-0.01	0.85	-0.01	>0.1
Relevance (Relevant) x Age (Children)	-1.48	0.8	-1.86	<0.07
Transmission mode (Demonstration) x Age (Children)	-2.36	0.98	-2.41	<0.05*
Relevance (Relevant) x Transmission mode (Demonstration) x Age (Children)	2.45	1.18	2.08	<0.05*
Marginal R^2: 0.14, Conditional R^2: 0.47				

We found significant main effects of action Relevance on Retention (figure 3), with participants being more likely to retain causally Relevant than Irrelevant actions overall.

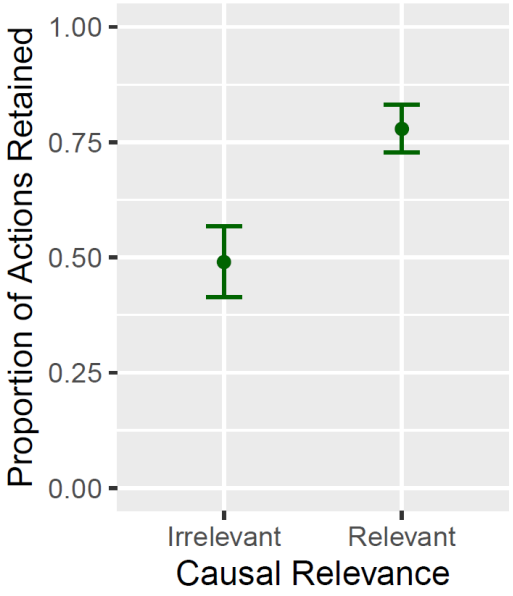

Figure 3. Proportion of causally irrelevant actions (left) and causally relevant actions (right) present in participants' input that were also present in their output.

We also found a significant effect of participant Age on Retention (figure 4), with Children retaining more actions than Adults overall.

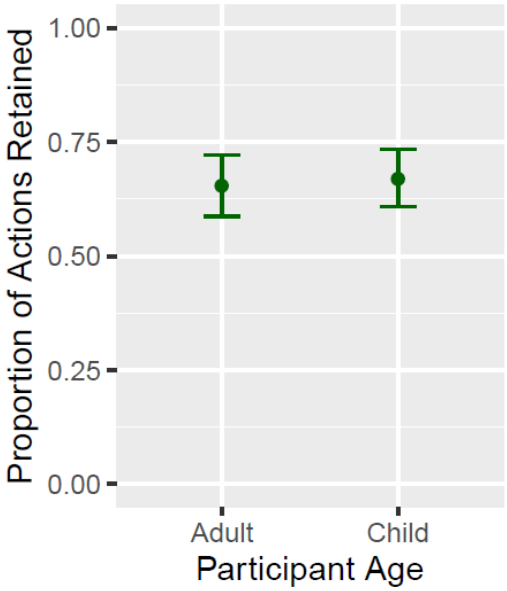

Figure 4. Proportion of actions present in participants' input that were also present in their output in the adult (left) and child (right) chains[1].

Transmission mode did not have a significant effect on Retention individually, but it produced three significant interactions: (i) Transmission mode x Age, (ii) causal Relevance x Age, and (iii) causal Relevance x Transmission mode x Age[2] (Table 3). To interpret these, Tukey post hoc comparisons were performed (see Appendix C; parts 1-3) using the lsmeans package (Lenth & Lenth, 2018).

[1] Age affected Retention, with the statistical significance of its effects becoming apparent when the random factors and variable interactions are accounted for in the analysis (as per in our GLMER model; se Table 3). Therefore, although Figure 4 does not illustrate the significance of the effects of Age (due to noise in the data used to construct it), it is presented here to illustrate the direction of its effects (i.e., Children retain more actions than adults overall).

[2] To assess their effect, we constructed a model which contained only causal relevance and participant age as fixed effects (i.e., not containing transmission mode) and random intercepts for participant and action. This was compared against our full model using the anova() function. Our full model was significantly better than the one excluding Transmission mode ($\chi 2 = 14.97$, $df = 4$, $p = 0.005$) and, therefore, the two interactions significantly affect Retention.

(i) Transmission mode x Age (figure 5): Pairwise comparisons indicated that Adults in the Verbal instructions condition retain less actions than Adults in the Demonstration condition (OR=0.34, SE=0.18, z-ratio=-2.04). Children in the Verbal instructions (OR=0.44, SE=0.22, z-ratio=-1.66) and in the Demonstration condition (OR=0.46, SE=0.24, z-ratio=-1.5) retain more actions than adults in the Verbal Instructions, and Transmission mode (OR=1.05, SE=.052, z-ratio=0.1) does not affect retention in Children as strongly as for Adults.

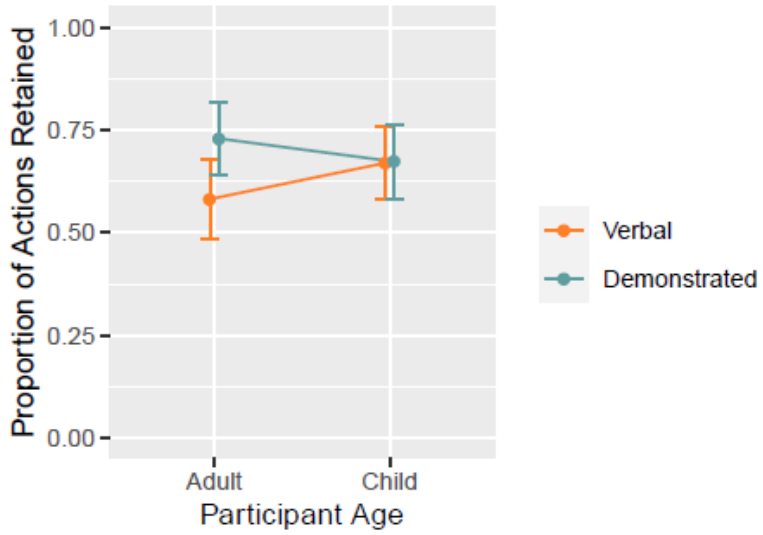

Figure 5. Proportion of actions present in participants' input that were also present in their output illustrating the 2-way interaction between Transmission mode and participant Age on action retention.

(ii) Causal Relevance x Age (figure 6): Pairwise comparisons indicated that both Adults (OR=0.19, SE=0.13, z-ratio=-2.46) and Children (OR=0.24, SE=0.15, z-ratio=-2.27) retain less causally Irrelevant than Relevant actions[3].

[3] The 2-way interaction between Age and causal Relevance was significant at an alpha level of 0.1 ($p<0.07$; see Table 3). We decided to present it here and to address it in the Discussion because, despite the fact that it does not meet the pre-registered threshold for statistical significance of $p<0.05$, we consider that it is worth exploring. Age and causal Relevance are often discussed in the literature, especially with regards to a developmental increase (or decrease) in the tendency to retain causally irrelevant elements of behaviours (see above). Interactions such as this could be taken into consideration when designing future studies that aim to address the effects of these factors on cultural transmission.

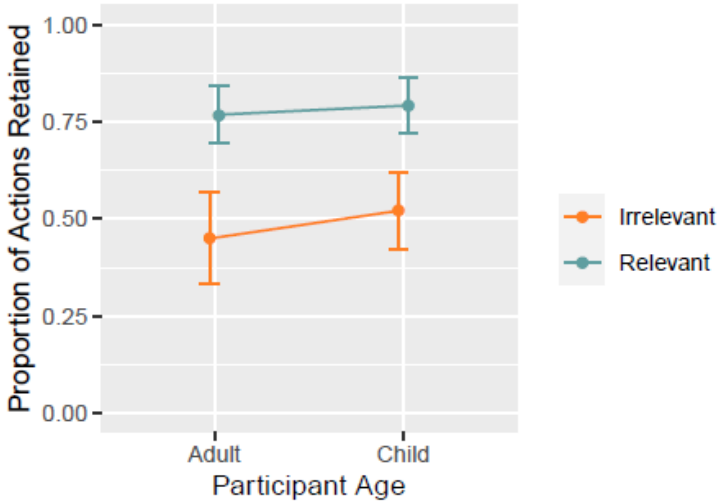

Figure 6. Proportion of actions present in participants' input that were also present in their output illustrating the effects of the 2-way interaction between causal Relevance and participant Age on action retention.

(iii) Causal Relevance x Transmission mode x Age (figure 7): Pairwise comparisons indicated an effect of Transmission mode on retention of causally Irrelevant actions (i.e., overimitation) by Children and Adults, with Adults overimitating more in Demonstration than in Verbal Instructions (OR=0.34, SE=0.25, z-ratio=-1.49), Children overimitating more in Verbal instructions than in Demonstration (OR=3.56, SE=2.19, z-ratio=2.06), Adults overimitating more than Children in Demonstration (OR=2.22, SE=1.48, z-ratio=1.19), and Children overimitating more than Adults in Verbal instructions (OR=0.21, SE=0.15, z-ratio=-2.25).

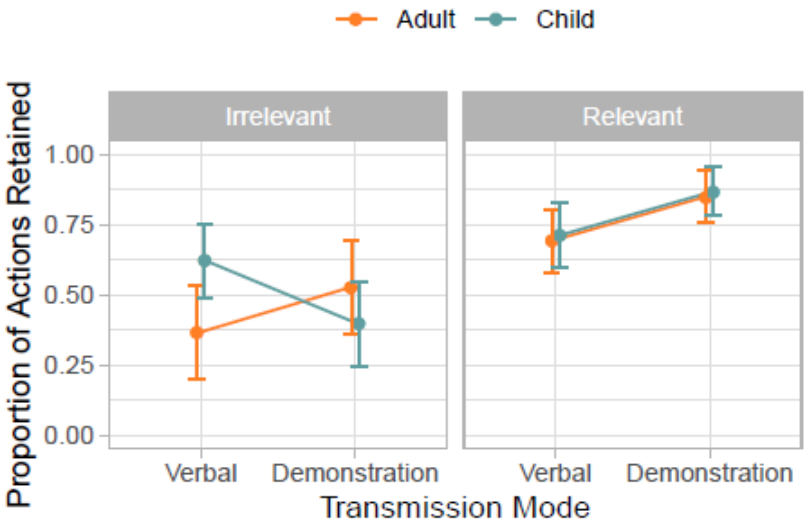

Figure 7. Proportion of actions present in participants' input that were also present in their output illustrating the 3-way interaction between Transmission mode, action causal Relevance and Age on action retention.

There were no significant differences in the retention of causally Relevant actions by Adults and Children in the Verbal instructions condition (OR=0.92, SE=0.53, z-ratio=-0.14) and in the retention of causally Relevant actions by Adults and Children in the Demonstration condition (OR=0.84, SE=0.58, z-ratio=-0.25).

3.2 Action innovation

At each generation, 20%, 35% and 19%, respectively, of all action tokens produced by a participant were innovations (actions not present in their input) (Table 2). A total of 31 action types were produced (89 tokens). The most common innovations were lifting the door open after seeing/hearing that the previous participant had slid it open and using the magnetic (red) end of the rod after having seen/heard the previous participant used the velcro (blue) end (Figure 8).

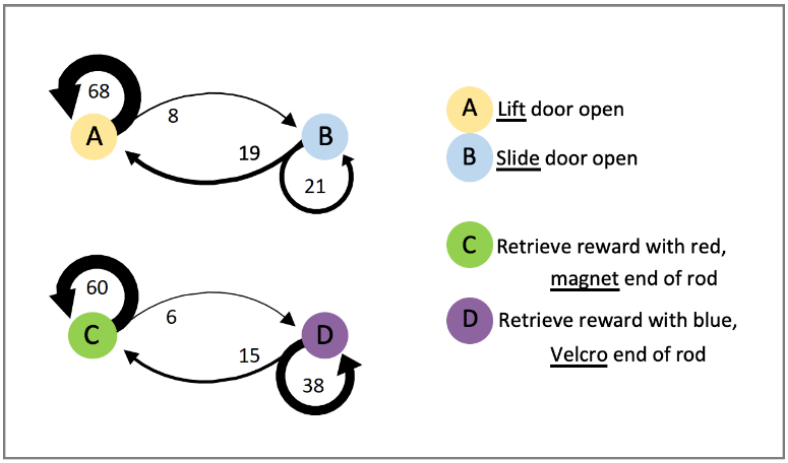

Figure 8. Number of times that the causally relevant actions in our seed sequences (Table 1) were retained (arrows from one action to itself) and innovated ('mutated' into one another) (arrows from one action to another) for opening the door (top) and retrieving the reward (bottom).

We found a significant effect of Transmission mode, ($\chi^2(1)=4.67$, $p<0.05$), with more Innovations in the Verbal Instruction (N=57) than the Demonstration condition (N=32) (figure 9); and no effect of age (adults N=39, children N=50) or Relevance (Relevant N=56, Irrelevant N=33).

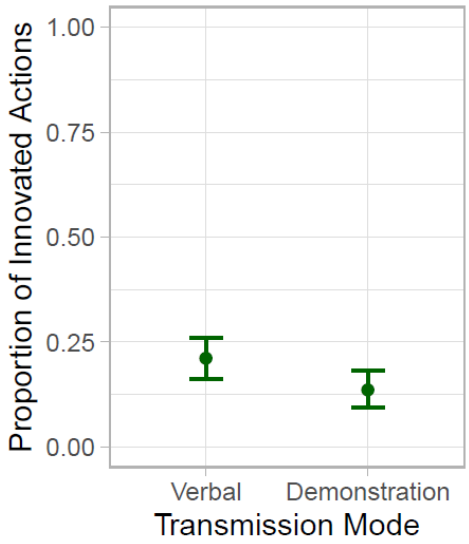

Figure 9. Proportion of actions that were innovated in the Verbal instructions condition (left) and in the Demonstration condition (right).

3.3 Cumulative improvement

The full model – containing all three fixed effects (Generation, Transmission mode, and participant Age) and their interactions – was significantly better than the null model ($\chi 2 = 26.47$, df = 11, $p<0.01$). Table 4 below summarises our full model.

Table 4. Summary of the model including Generation, Transmission mode, and participant Age as fixed effects, and random intercepts for chain.

Model: Generation * Transmission Mode * Age + (1 | Chain)				
	Estimate	**SE**	***z*-value**	***p*-value**
Generation (Linear)	0.89	0.51	1.73	<0.09
Generation (Quadratic)	-0.99	0.67	-1.48	>0.1
Transmission Mode (Demonstration)	-0.74	0.42	-1.75	<0.09
Participant Age (Child)	-1.45	0.40	-3.61	<0.001***
Generation (Linear) x Transmission Mode (Demonstration)	-0.77	0.66	-1.17	>0.1
Generation (Quadric) x Transmission Mode (Demonstration)	0.85	0.80	1.07	>0.1
Generation (Linear) x Participant Age (Child)	-0.73	0.61	-1.19	>0.1
Generation (Quadratic) x Participant Age (Child)	1.21	0.75	1.62	>0.1
Transmission Mode (Demonstration) x Participant Age (Child)	1.54	0.54	2.85	<0.01**
Generation (Linear) x Transmission Mode (Demonstration) x Participant Age (Child)	1.67	0.89	1.87	<0.07
Generation (Quadratic) x Transmission Mode (Demonstration) x Age_Group1	-0.79	0.97	-0.81	>0.1
Marginal R^2: 0.13, Conditional R^2: 0.13				

Generation affected cumulative improvement. Fig. 10 shows that this is driven by a linear decrease in the number of Irrelevant actions over generations, while the number of Relevant actions remains stable. This decreasing proportion of Irrelevant actions over generations is our definition of cumulative improvement in efficiency.

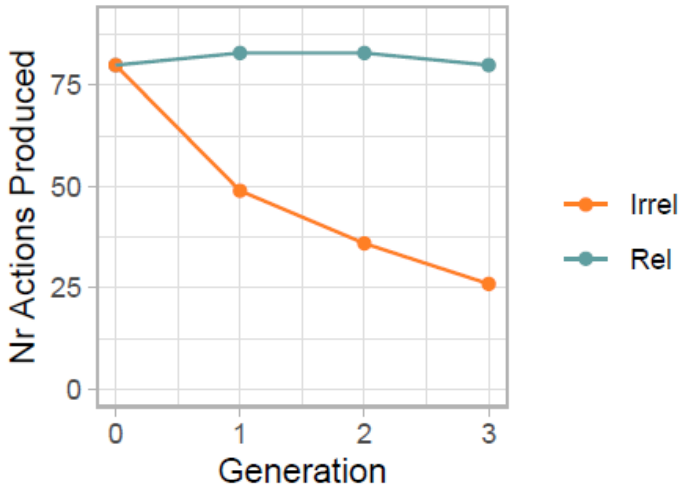

Figure 10. Number of causally relevant and irrelevant actions produced at each generation, illustrating the cumulative improvement in efficiency. Generation 0 shown, but not included in analysis.

Participant Age also affected cumulative improvement, with a larger decrease in the proportion of irrelevant actions by Adults than by Children (figure 11).

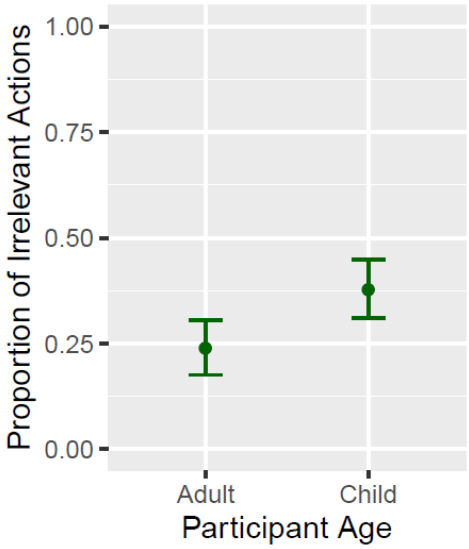

Figure 11. Proportion of relevant actions produced by Adults and by Children. Note that Fig. 10 shows action counts while this one shows proportions.

Transmission mode had a smaller effect, with a larger decrease in the proportion of irrelevant actions in the Demonstration than in the Verbal Instructions condition (figure 12).

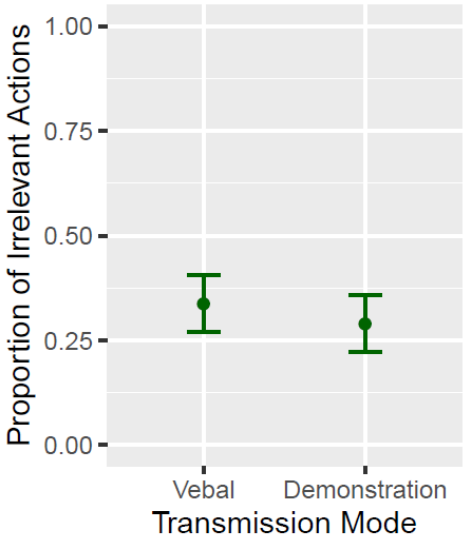

Figure 12. Proportion of relevant actions produced by participants in the Verbal Instructions (right) and Demonstration (left) condition.

Two significant interactions were produced: (i) Transmission mode x Age and (ii) Generation x Transmission Mode x Age, which were interpreted by performing Tukey post hoc comparisons (see Appendix C; parts 4, 5) using the lsmeans package (Lenth and Lenth 2018).

(i) Transmission Mode x Age (figure 13): Pairwise comparisons indicated that, in the Verbal instruction condition, Adults lose more irrelevant actions than Children (OR=4.25, SE=1.71, z-ratio=3.61). In addition, Children lose more irrelevant actions in Demonstration than in Verbal instructions (OR=0.45, SE=0.15, z-ratio=-2.37).

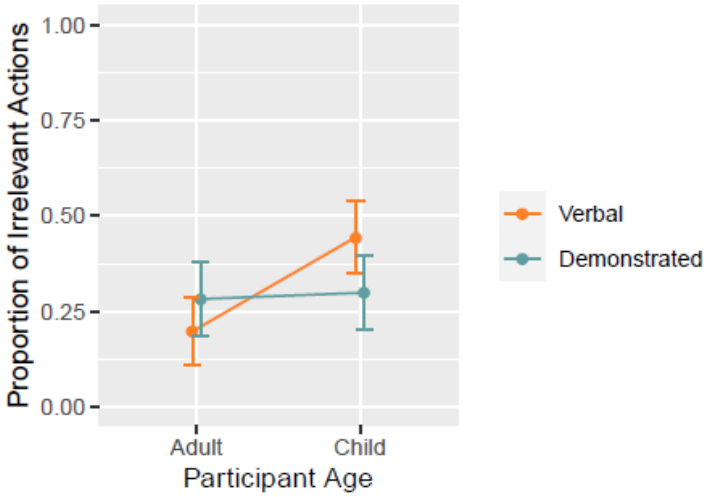

Figure 13. Proportion of relevant actions produced by participants illustrating the 2-way interaction between Transmission mode and participant Age.

(ii) Generation x Transmission Mode x Age (figure 14): Pairwise comparisons indicated an effect of Transmission mode on the loss of causally irrelevant actions (i.e., increase of cumulative improvement) by Children and Adults, with Adults achieving more cumulative improvement by the third Generation in comparison to the first in Verbal instructions (OR=0.29, SE=0.21, z-ratio=-1.73) but not in Demonstration; in Verbal instructions, generation 3 in Adults, also, achieves more cumulative improvement than Generation 3 in Children (OR=4.34, SE=3.12, z-ratio=2.05). In contrast, Children achieve more cumulative improvement by the third Generation in comparison to the first in Demonstration (OR=0.22, SE=0.16, z-ratio=-2.1), but not in Verbal instructions, and Generation 3 in Adults achieves less cumulative improvement than Generation 3 in Children in Demonstration (OR=0.39, SE=0.29, z-ratio=-2.05).

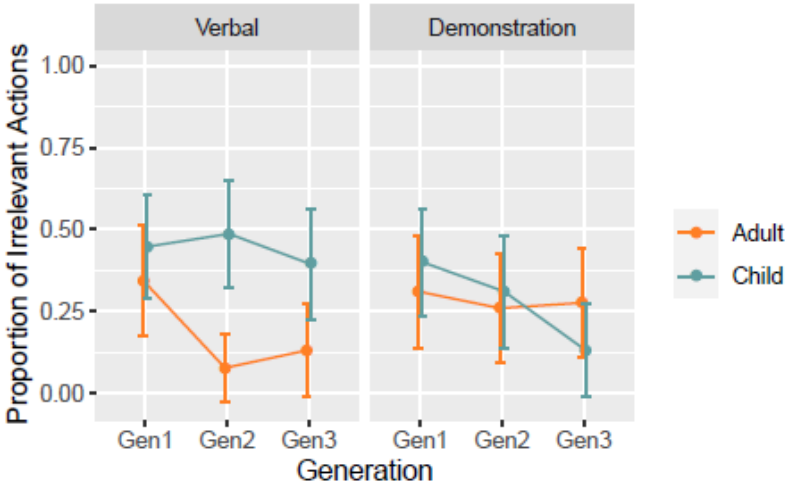

Figure 14. Proportion of irrelevant actions produced by generation and condition illustrating the three-way interaction between Generation, Age and Transmission.

4 Discussion

The main objective of the current study was directly and systematically to compare for the first time the effects of purely language-based transmission (which did not allow gesture or other visual cues) against visual demonstration (the transmission modality used in most previous studies of social learning) on social learning and cultural evolution. We analysed the extent to which actions were retained by participants, how much innovation they introduced and how the efficiency of action sequences cumulatively evolved over three generations. Our sequences included causally relevant and irrelevant actions to test the effects of transmission mode on imitation and overimitation, respectively, and we included adult and 6-8-year-old participants

to explore developmental effects. We also set out to investigate the effects of action familiarity, but a design defect precluded analysis.

Both our adult and child participants retained a proportion of the irrelevant actions present in their input. This contributes to the established body of evidence of overimitation in humans. In the control condition, participants produced a few causally irrelevant actions, but they were in all likelihood exploratory, and could have turned out to be causally relevant (e.g., try to extract the reward with their fingers). In the transmission chains, in contrast, it was obvious that at least some actions were not necessary, but they were nevertheless copied, indicating that participants were much more likely to produce manifestly superfluous actions in the context of social learning than asocial learning.

We found support for our first and third hypotheses, namely more retention of relevant than irrelevant actions, in line with previous studies (e.g., Flynn, 2008; McGuigan & Whiten, 2009; McGuigan & Graham, 2010; McGuigan et al., 2011), and the cumulative loss of irrelevant actions over generations. However, our results did not support hypothesis 2, which predicted more overimitation by adults than children.

We did not have specific hypotheses regarding the effects of our key manipulation of transmission modality. The results yielded marginally less action copying in purely language-mediated transmission than in demonstration-based transmission. This effect was significant for imitation and overimitation by adults, and imitation by children. Interestingly, the exception was overimitation by children, which was significantly higher under verbal transmission than under demonstration. In other words, when presented with causally *relevant* actions, all our participants imitated more when the actions were demonstrated visually than when they were conveyed verbally, that is, they imitated more when they saw the actions than when they were told about them. (When they did not imitate a causally relevant action, they innovated: they replaced it with an unobserved action that would allow them to complete the task). When presented with causally *irrelevant* actions, adults did the same, they copied more what they saw than what they were told about. However, children behaved in the opposite way –they reproduced fewer of the causally irrelevant actions they saw than of the actions they were told about. This suggests that, when it comes to imitation, verbal transmission increases the likelihood that participants of any age ignore, forget or misunderstand (or perhaps be more inspired to be creative) compared to visual demonstration. The same is the case with

overimitation in adults. When it comes to overimitation in children, in stark contrast, verbal transmission contributes to fidelity.

Even though the majority of actions were retained, many participants introduced innovative actions that were not present in their input. For instance, a participant tilted the box towards them, so the ball rolled out of the door and, therefore, it was not necessary to use the rod; another one pushed the door open with the rod, instead of with their hand. When asked why they had replaced actions in their input with new ones, some participants responded that they could not remember the exact actions in the input, or that they thought that was the way to do it. Most of them, however, were not sure why they had innovated. The majority of the innovative actions introduced by participants in the transmission chains were causally relevant, and the same was the case in the control group, where participants who attempted to extract the reward without any previous demonstration or verbal instruction produced overwhelmingly more relevant than irrelevant actions, indicating that participant performance tended to be goal-oriented.

More innovation occurred under verbal instructions than under observation. A possible reason for the lower transmission fidelity (less retention and more innovation) observed under verbal instruction than demonstration is the visual absence of the model in our audio-recorded instructions. This possibility can be tested by conducting a similar study in which video input is presented in both conditions, but in one the model demonstrates and in the other narrates the action sequence. Alternatively, lower fidelity under the verbal instruction condition may be due to language underspecification (e.g., Frisson, 2009). For a physical task such as extracting a reward from a box, the meaning conveyed by verbal signals is less detailed and more ambiguous than the meaning conveyed by visual demonstration. The meaning of a verbal signal (in our case, an instruction) is shaped by the listener's prior knowledge and by the context. Suppose a participant hears 'swipe the rod three times on the side of the box'. In order to carry out the instruction, they have to access their own meaning for swipe, rod, three, etc. While some signals are unambiguous for most speakers (e.g., three times) others, such as swipe, can be interpreted in multiple ways (e.g., swipe upwards, downwards, from left to right etc; holding the rod with two fingers or with the whole hand, etc; fast or slowly, etc). Demonstration provides a level of detail that significantly narrows down interpretation. This could explain some of our results, but not the higher retention of irrelevant actions (overimitation) by children under verbal transmission. Indeed, children retained relevant and irrelevant actions to the same

degree when they were verbally instructed (Fig. 3). This exception may be explained by links between language and normativity.

Overimitation in children has been related to a psychological tendency to participate in rituals –conventional, causally opaque action sequences– which, in turn, facilitate social affiliation (Wen et al., 2016), and to normativity, the belief that it is somehow obligatory to copy behaviour faithfully (Keupp et al., 2013), which may promote cooperation (Rakoczy et al., 2009). Children tend to assume socially learned actions are normative to the extent that they denounce others who perform modified versions of the actions. They display normative behaviour after adult models give normative instructions (Casler et al., 2009; Rakoczy et al., 2008), and even when the adult's language is not explicitly normative (Schmidt et al., 2011). Language elicits normativity and maintains rituals (e.g., saying "I will show you how it works" implies the behaviour shown is the norm or a ritual), and this may be the explanation why our children overimitate more under verbal instruction. This hypothesis could be tested with direct comparisons of the effects of normative language, non-normative language and no language (e.g., non-verbal demonstration). If it were supported, it would speak to the question of language origins, suggesting that language may have coevolved with transmission fidelity. By eliciting normative and ritual behaviour in childhood, language would support the faithful transmission of behavioural patterns (even patterns whose function is not understood), which is required for cumulative cultural evolution (Tamariz, 2019), early in life. The fact that overimitation is facilitated by verbal transmission in children, but not in adults might indicate that the normative function of language changes over the lifetime. Studying language- and demonstration-mediated social transmission in a range of ages, from early childhood through adolescence and adulthood to old age, would tell us when and how this happens. These studies would provide data about the contribution of individuals at different life stages to social transmission, which could in turn inform models of cultural evolutionary dynamics in populations with different age distributions.

Our results for the demonstration condition show no difference between adult and child overimitation levels, in line with some previous studies that also used demonstration (Whiten et al., 2016), but different from others, which found an increase in overimitation with age (e.g., McGuigan et al., 2011; McGuigan, 2012). In our verbal condition, intriguingly, children overimitated more than adults. This might be due to qualitative differences between the verbal instructions produced by children and adults. Children's utterances could be less complex or more straightforward than adults', and they could facilitate production of causally irrelevant

actions. Or children's language might be more goal-oriented, and therefore more suited to instructions about causally relevant actions. But if that were the case, we would not have the distinction between causally relevant and irrelevant actions; instead, we would expect children's retention of actions to be higher in all verbal instruction conditions - for both relevant and irrelevant actions. Despite that, in order to check whether the differences in children's and adults' speech affected their likelihood of retaining an action in the verbal instructions condition, we transcribed children's and adults' descriptions of the same sequences of actions and compared their narrative styles: which verbs and nouns they used and in what numbers, in which person the verbs were, the length of the descriptions and the number and length of their pauses. We did not find any substantial differences that might account for increased retention in children, so we may conclude that it was the mode of transmission that affected differential retention in children and adults. The country in which the experiment took place could also have contributed to age related differences in overimitation. Cross-cultural differences can affect children's overimitation (Berl & Hewlett, 2015; Clegg & Legare, 2016), and the primary education system in Cyprus, more teacher-centred than other western systems (Papanastasiou, 2002), could have biased our child participants to be more compliant with verbal instructions. In Cyprus, teachers traditionally provide instructions and teach children to follow them from a young age. Many of our adult participants were either current students or (recent) graduates of European universities, where they were most probably exposed to more student-centred educational systems. However, based on the results of our study, we cannot know for certain what accounts for the developmental decrease in overimitation under verbal instruction: did Cypriot adults overimitate less or did Cypriot children overimitate that much more? Studies of language-mediated social transmission with children and adults from countries with different educational styles could shed more light on this question and, by extension, on the effects of the educational system on social learning and cultural evolution.

Our findings, therefore, suggest that verbal transmission generally reduces transmission fidelity compared to demonstration, except in the case of overimitation by children, which is facilitated by verbal transmission. This result is mirrored in the analysis of cumulative change over generations, which is simply a different way to approach the same data now taking generations into account. We operationalised cumulative improvement in efficiency as a reduction in the proportion of causally irrelevant elements produced in the action sequence leading to the extraction of the reward from the box. We found a greater loss of irrelevant actions over the generations under demonstration than verbal instruction; in other words, language reduced

cumulative improvement in efficiency, reflecting Putt et al.'s (2014) finding that the individual actions of participants learning how to make bifaces were more efficient in the demonstration-only condition compared with demonstration plus language. Moreover, we found cumulative increases in efficiency in adults in the verbal condition and children in the demonstration condition.

We might equate our measure of cumulative increase in efficiency with cumulative cultural evolution and conclude, first, that the relatively higher cumulative efficiency gains under demonstration is evidence that language reduces cumulative culture and second, that, specifically, adults under verbal instruction and children under demonstration show cumulative culture. However, we interpret these results in the opposite way. Our metric of cumulative improvement is based on the principle that eliminating irrelevant actions improves the efficiency of the task at hand. If we take a longer-term evolutionary perspective, we see that this operationalisation actually runs against cumulative cultural evolution: Cumulative cultural evolution results in cultural traits that could not have been invented by a single individual, and these are passed on from generation to generation (Tomasello, 1990; Tennie et al., 2009). Such traits can be complex and opaque, so their causal relevance will not be immediately obvious to the learner. The retention of opaque traits cannot be achieved by imitators, who are focused on ends, or goals. Instead, it requires copiers who focus on means, i.e., on the form of actions, such as overimitators. In our study, children failed to improve the efficiency of action sequences over generations under verbal instruction (as did adults under demonstration, but their levels of action retention were much lower) (Fig. 6). This is because they did not lose (i.e., they retained) causally irrelevant actions (see results on retention above). We can therefore conclude that verbal instruction is a conservative transmission modality that promotes the faithful retention of causally irrelevant (and potentially opaquely functional) behaviour in children, but not in adults.

Putt et al. (2014) also found higher transmission fidelity in the form of more precise reproduction of actions when verbal instruction was added to demonstration of stone-tool manufacture, a highly complex skill. Their participants, however, were adults. Tamariz (2019) argues that the essential component of cumulative culture is the replication of actions, regardless of whether their function is understood or not, by naïve learners. Putt et al.'s (2014) adult learners were naïve to their complex task. Our child participants were also arguably naïve to the task of extracting a reward from a strange-looking box. Our adult participants were also naïve to this task, but to a lesser extent than the children. Children are still capable of magical

thinking and entertaining supernatural beliefs (Wooley, 1997; Subbotsky, 2004), which makes them much more naïve, bias-free, open-minded when faced with our causally irrelevant actions. Adults, in contrast, will more readily see the causally irrelevant actions for what they are and, under a rational efficiency bias, they will be less likely to copy them. Therefore, we can say that both in Putt et al. (2014) and our study, language increased transmission fidelity by naïve (but not by experienced) participants. We resume the idea mentioned above and put forward the hypothesis that language selectively increases blanket copying (McGuigan et al., 2010) or action replication (Tamariz, 2019) by naïve learners, and that it enhances not only overimitation, but also the reproduction of the precise structure, or style, of causally relevant actions. (These, in turn, support cumulative cultural evolution which, we should add to close the circle, in turn increases human fitness, e.g., Mesoudi & Thornton, 2018). This hypothesis can be tested by comparing verbal and demonstration-based transmission using tasks that are either truly novel or familiar for the participants.

The action sequences in this study had a very specific goal, namely, to extract a reward from a box. Other experiments exploring verbal transmission versus demonstration used similarly physical or technological goals such as manufacturing stone tools (Ohnuma et al., 1997; Morgan et al., 2015; Putt et al., 2014), baskets (Zwirner & Thornton, 2015), etc. Cultural traditions, however, are hugely diverse, and transmission and innovation operate differently across cultural domains (Tamariz et al., 2016). We do not know whether our findings apply to other cultural traits such as complex behaviour, ideas, beliefs, values etc. Extensions of the current study may help reveal how transmission fidelity and innovation in children and adults operate under language- and demonstration-based transmission for a variety of cultural traditions.

In conclusion, this study has shed light on how language shapes the operation of the dual engines of cultural evolution –copying and innovation (Legare & Nielsen, 2015). We have found that, compared to demonstration, verbal transmission increases innovation; reduces imitation in children and adults; reduces overimitation in adults; and, most interestingly, facilitates overimitation in children. Moreover, under verbal instruction, children overimitate more than adults –the first experimental instance in which this is the case–, suggesting a developmental role of language-mediated social transmission. The evolutionary consequences of increased overimitation in children at the population level and in the long term include higher retention of opaque actions over generations, which suggests a novel explanation for language origin: Language might have evolved in part because it facilitates the faithful transmission of

opaque behaviour to early learners and, thus, it supports cumulative cultural evolution. This corollary should be further explored with especially designed studies.

Chapter 3

Context of learning behaviours and the model biases on cultural transmission

Abstract

The social transmission of cultural traits from transmitter to learner can follow different cultural transmission pathways: vertical (from a member of one generation to a biologically related member of a succeeding generation), oblique (from a member of one generation to a biologically unrelated member of a succeeding generation), and horizontal (from a member of one generation to another member of the same generation). These attribute different characteristics to the transmitter, which – along with other factors – affect the likelihood that a learner will copy his/her behaviour (model-based biases). Yet, we still do not know what the learners, once they become transmitters, transmit onward to other learners and which factors affect onward transmission. This study tests whether the likelihood that a cultural variant is transmitted onward is affected by the social relationship between participant and learner during acquisition. Participants were presented with two strategy variants to solve a problem, one from an Expert *and* one from a Peer (acquisition phase). Then, they were asked to transmit onward one variant to a perceived novice *or* transmit onward one variant to a perceived peer (onward transmission phase) and we measured how often they chose to transmit onward each variant. Our results support that a model-based bias affected their choice, as they transmitted onward the Expert's variant overall. However, participants associated the strategy with the role of the transmitter and the learner during acquisition. As such, a context-congruence bias modulated the model-based bias, with participants transmitting onward to their *peer* significantly more often the Peer's strategy than when transmitting onward a strategy to a *novice*. The context-congruence bias is the first factor found to link acquisition and onward transmission and it can be used to predict the longevity and stability of cultural traits.

1 Introduction and Literature Review

Human culture is extraordinary, and its complexity – highly attributable to its ratchet-like evolution (Tomasello, 1999; Tomasello, Kruger, & Ratner, 1993) – renders it unique in the animal kingdom (Boyd & Richerson, 1995). The social transmission of cultural traits has been extensively studied (see reviews by (Hoehl et al., 2019; Legare, 2017; Whiten, 2019; Whiten & van de Waal, 2017); in the laboratory (e.g., Baum, Richerson, Efferson & Paciotti, 2014; McGuigan & Cubillo, 2013; Caldwell & Millen, 2008; Mesoudi & Whiten 2004), with the usage of mathematical models (e.g., Aoki & Feldman, 2014; Kempe, Lycett & Mesoudi, 2014; Lewis & Laland, 2012; Boyd & Richerson, 1985) and agent-based computer simulations (Mesoudi & O'Brien, 2008; Rorabaugh, 2014), and even in real-world paradigms (e.g., Henrich & Henrich, 2010; Beheim, Thigpen & McElreath, 2014). We are now beginning to fully understand who and what constitute biases on cultural transmission, thereby influencing the new learner's behaviour and the behaviour they will adopt from the transmitter(s) (Mesoudi & Whiten, 2008; Smith, Kalish, Griffiths & Lewandowsky, 2008; Whiten & Mesoudi, 2008; Whiten, Caldwell & Mesoudi, 2016).

Transmitters and learners can have different relationships, formed by different transmission pathways (Boyd & Richerson, 1985; Cavalli-Sforza & Feldman, 1981; Hewlett & Cavalli-Sforza, 1986; Mesoudi & O'Brien, 2008). Depending on the trait, a learner might be more likely to adopt its vertically transmitted variant – i.e., the one transmitted from parent(s), its obliquely transmitted variant – i.e., the one transmitted from older individuals other than the parents (e.g., a teacher), or its horizontally transmitted variant – i.e., the one transmitted from peer(s) (Adler, Kless, & Adler, 1992; Baker, Little, & Brownell, 2003; Cavalli-Sforza, Feldman, Chen, & Dornbusch, 1982; Schönpflug, 2001).

Biases

Previous research supports that human cultural transmission is "highly biased toward particular representations" (Henrich, Boyd & Richerson, 2008; p.121). Studies have focused on revealing and examining such biases, as well as the strength of their effects on cultural transmission (O'Gorman, Wilson & Miller, 2008; Mesoudi, Whiten & Dunbar, 2006; Mesoudi & Whiten,

2004; Bangerter, 2000; Kashima, 2000). Pioneering research was conducted by Boyd and Richerson (1985), who proposed, among others, the content-based bias. According to this, an individual's likelihood of copying a variant is affected by the intrinsic properties and characteristics of that variant.

Model-based Bias

Of particular interest to this study, is their proposed model-based bias (Boyd & Richerson, 1985). According to this, the characteristics of a transmitter can increase (or, decrease) the likelihood that a learner will copy his/her behaviour. Such characteristics include status (McGuigan, 2013; e.g., having a position of authority; Reyes-Garcia et al., 2008), age (Henrich & Gil-White, 2001; Wood, Harrison, Lucas, Mcguigan, Burdett & Whiten, 2016), knowledge (Henrich & Gil-White, 2001), success (Reyes-Garcia et al., 2008) and homophily (Buttelmann, Zmyj, Daum, & Carpenter, 2013; Kinzler, Shutts & Spelke, 2012).

Henrich and Gil-White (2001) concluded that individuals are biased to copy successful individuals who have real or perceived skill; a strategy which can prove adaptive, as those individuals will, potentially, be more successful than others in their environment (Price, Wood, & Whiten, 2017). Social prestige, along with age, are cues used by learners to infer their model's expertise (Henrich & Gil-White, 2001; Jimenez & Mesoudi, 2019). As follows, adults prefer to copy prestigious individuals - those who others spend more time observing (Atkisson, O'Brien & Mesoudi, 2012). Children are more likely to copy other children when their actions are effective (Azmitia, 1988), but they tend to copy adults over children (Chudek, Heller, Birch, & Henrich, 2012; McGuigan, Makinson, & Whiten, 2011), regardless of whether they report being experts or not (Wood, Kendal & Flynn, 2012).

Transmission Pathways

An important aspect of the model-based bias can be derived from the social relationship formed between transmitter (i.e., the one who transmits information) and learner (i.e., the one who acquires the transmitted information). Cavalli-Sforza and Feldman (1981) distinguished between three cultural transmission pathways, each of which attributes different characteristics to the model/transmitter: vertical (from a member of one generation to a biologically related member of a succeeding generation), oblique (from a member of one generation to a biologically unrelated member of a succeeding generation), and horizontal (from a member of one generation to another member of the same generation).

According to the developmental stage of the learner, a different pathway is dominant over the others (Henrich & Broesch, 2011; Henrich & Henrich, 2010; Hewlett, Fouts, Boyette, & Hewlett, 2011), so the learner is more likely to acquire the traits of certain transmitters over others.

Vertical/Oblique Transmission

Vertical transmission is dominant during infancy and early childhood (Hewlett, Lamb, Leyendecker, & Schölmerich, 2000; Reyes-Garcia, Gallois, & Demps, 2016), and it is considered the most adaptive transmission pathway from an evolutionary perspective. The parents – the transmitters most likely to learn from during this stage – are the most motivated individuals in their child's social environment to transmit to her the variants they deem most beneficial (Boyd & Richerson, 1985), even at the cost of their own fitness (Birch & Okasha, 2015). As long as the environmental conditions do not radically change to the point where a different variant becomes more adaptive (Schönpflug, 2001), it is likely that, once that child becomes a parent herself, she will transmit onward to her children the same cultural variant that her parents had transmitted to her.

Research has shown that complex traits such as political tendencies (Funk et al., 2013; Jennings & Niemi, 1968; Ojeda & Hatemi, 2015), academic values (Jodl, Michael, Malanchuk, Eccles, & Sameroff, 2001), religion, entertainment, sports, superstitions and beliefs, customs and habits (Cavalli-Sforza, Feldman, Chen & Dornbusch, 1982) tend to be transmitted vertically, thus leading to high degrees of attitude concordance between parents and their children (Dalhouse & Frideres, 1996; Miller & Glass, 1989; Vollebergh, Iedema, & Raaijmakers, 2001). This intergenerational congruence, facilitated by humans' capacity for faithful imitation and transmission of traits across generations (Tomasello, 1999; Caldwell & Millen, 2008), has allowed the continuity and preservation of cultural information for at least two biological generations (Cavalli-Sforza, Feldman, Chen & Dornbusch, 1982), while it often leads to cultural products – such as traditions – which are passed on for many more generations (Tomasello, 2009; Caldwell & Millen, 2008; Mesoudi & Whiten, 2008; Boyd & Richerson, 1996; Rubin, 1995).

Cultural evolutionary studies often conflate vertical and oblique under the label "vertical" (e.g., (Nielsen et al., 2012; Pagel & Mace, 2004; Theisen-White, Kirby, & Oberlander, 2011). In these, the effects of the model-based "vertical" bias are evident – i.e., the preference to copy an older, a more prestigious, or a more expert model. Children in these studies are more inclined

to copy the actions of adults as opposed to those of other children (Wood et al., 2016; Seehagen & Herbert, 2011; Jaswal & Neely, 2006). For instance, when witnessing the performance of novel actions by both adults and peers, children imitate the actions of the adult models over those of the child models (Zmyj, Aschersleben, Prinz & Daum, 2012a). Moreover, Nagle (1976) found that children would more readily imitate the actions of a highly competent teacher model than those of a highly competent peer model. Zmyj et al. (2012b) also found that fourteen-month-old infants' imitative tendencies increase as the age of the model increases; they tended to imitate adults more often than they tended to imitate younger models. Finally, Cheng and Chartrand (2003; Study 2), found that adults are more likely to imitate the actions of those whom they perceive as their superiors.

Horizontal Transmission

Later in life, however, as horizontal transmission becomes the dominant pathway (Hewlett et al., 2011), learners become most likely to acquire the traits of their peers (Cavalli-Sforza & Feldman, 1981). As Seehagen and Herbert (2011) have shown, children's tendency to imitate peers more readily than adults increases as a function of age, with the older infants in their study retaining significantly more often the information they learned from their peers than from adults.

As horizontal cultural transmission can only guarantee the conservation of the transmitted information for one biological generation (Cavalli-Sforza & Feldman, 1981), it has been associated with less complex traits, such as taste in clothes and hair (Remmers & Radler, 1957), consumer socialisation (Churchill & Moschis, 1979), social skills (Adler, Kless, & Adler, 1992), drinking behaviours (Borsari & Carey, 2001; DiGuiseppi, Meisel, Balestrieri, Ott, Cox, Clark, & Barnett, 2018; Ding, Newman, Buhs, & Shell, 2018), smoking (Adebiyi, Faseru, Sangowawa, & Owoaje, 2010; Harakeh, Engels, Van Baaren, & Scholte, 2007; Antonuccio & Lichtenstein, 1980) and eating behaviours (Baker, Little, & Brownell, 2003; Maximova, McGrath, Barnett, O'Loughlin, Paradis, & Lambert, 2008).

Rogers (2010), argues that homophily – i.e., the tendency to imitate those who are similar to oneself – allows for more efficient communication, and it is more likely to lead to behaviour change. Additionally, Zmyj et al. (2012) found that a child's association of a model with herself can have a significant effect on the probability that she will copy that model (even in the absence of communicative context), as identifying a model as "like me" (Meltzoff, 2005) leads to the "peer model advantage in infant imitation" (p. 2; see also Nadel, Guérini, Pezé, & Rivet,

1999). Similarly, children tend to copy children over adults in a novel toy task (Wood et al., 2016) and, generally, tend to imitate their peers' behaviours, as part of their ingroup identity (Johnson, 1981).

The effects of a model-based "horizontal" bias have also been observed in adolescents and adults (Card & Giuliano, 2013; Kassarnig, Bjerre-Nielsen, Mones, Lehmann, & Lassen, 2017; de Paola, 2010), with peers in these developmental stages showing behavioural congruence. Yabar, Johnston, Miles, and Peace (2006) found that, when participants perceive a model as part of their group (i.e., similar to themselves), they are more likely to imitate their gestures than the gestures of a model whom they perceive as someone outside their group, even if both models perform the same gestures. Cheng and Chartrand (2003; Study 1) have also found that participants were more likely to imitate the gestures of a confederate, when they perceived her to be a peer. Finally, Webb and Sheeran (2006) found that behaviour-change interventions delivered by research assistants (non-experts) had a larger impact on behaviour than when they were delivered by experts.

In summary, much research has focused on which cultural variants learners will adopt for themselves and how cognitive biases – such as the model-based bias – may affect that choice. The results are conflicting, thus creating a gap in the literature: some suggest that a model-based vertical bias affects the learner's choice, leading to a tendency to adopt the variants of older, more expert, or more prestigious transmitters. Others suggest that a model-based horizontal bias has a stronger effect on that choice, with learners preferring to adopt the variants of the transmitters who are most like themselves – i.e., who are identifiable as "peers".

However, we still do not know what the learners, once they become transmitters, choose to transmit onward. Over the course of our development, we learn different strategies to solve problems, from social, technological, or linguistic down to everyday situations. For instance, to socialise with others and form new friendships, one might have learned from someone that it is a good strategy to ask interesting questions and from someone else that it is effective to make jokes and share anecdotes. Or, a child might have learned from her mother that, to keep a boiling egg from cracking, a good strategy is to pour some vinegar in the water, whereas another strategy learned from a friend of hers would be to add a lemon wedge in the water. So, from enhancing our bonds with others to boiling eggs, we often acquire more than one variant of the same trait. But which variant is chosen to be transmitted onward and which factors may bias this choice? This paper goes beyond biased transmission to explore the effects of model

bias not on adoption of cultural traits, but on their onward transmission once the learner becomes the transmitter.

Associative Learning

The inconsistencies in the literature could be addressed by considering the role of associative learning (Pavlov, 1927; Bichler, Zhao, Alibart, Pleutin, Lenfant, Vuillaume, & Gamrat, 2013 etc.) during cultural transmission. Associative learning takes place when a learner connects two events. Of these events, one refers to, signals, co-occurs with, or causes the other (Molchan, Sunderland, McIntosh, Herscovitch, & Schreurs, 1994; Shanks & Darby, 1998; Grillon, 2002; Mitchell, De Houwer & Lovibond, 2009). It has been previously suggested to account for imitation – i.e., a learner's reproduction of a model's observed behaviour (Heyes & Ray, 2000) – and to be involved in the acquisition of complex traits, such as word-learning (Wasserman, Brooks, & McMurray, 2015).

Heyes and Pearce (2015) have argued that associative mechanisms "make learning selective" (p. 6) and they can be viewed as learning strategies. Thus, a learner may use social (and asocial) cues to "decide" which traits to acquire. During cultural transmission, specifically, learners could be associating the variant they deem best to acquire for themselves with the transmitter who has a specific relationship with them. For example, an individual will acquire the political orientations of his parent(s) (Funk et al., 2013; Ojeda & Hatemi, 2015), because of their parent-child relationship, while that same individual will acquire the social skills of a peer (Adler, Kless, & Adler, 1992), because of their peer-peer relationship.

As such, a congruence in cultural traits arises between two consecutive generations (the transmitter and the learner) – whether these are vertical (e.g., parent-child) or horizontal (peer-peer) generations – and this determines the nature and complexity of the traits (Cavalli-Sforza, Feldman, Chen, & Dornbusch, 1982). In general, the traits which are more relevant to our survival – such as subsistence and childcare skills – tend to be transmitted vertically (Hagen, van der Ploeg, & Minter, 2017; Hewlett et al., 2011), thereby persisting for generations. Vertical cultural transmission can sometimes be from just one of the parents to the child. Specifically, evidence suggests that there exists a higher behavioural congruence in the mother-daughter and father-son dyads than the father-daughter and mother-son dyads (e.g., Rapoport, 1985; Reyes-Garcia et al., 2009; Shennan & Steele, 1999).

We wonder to what extent these patterns are due to the impact of the context of acquisition whereby a woman transmits to her daughter cultural variants she acquired from her mother, a student transmitting to a classmate something acquired from another classmate and so on. Though we would expect a model-based bias to affect the choice of trait acquisition (e.g., the learner will show a preference for acquiring social skills from the most popular peer) we argue that a context-congruence bias, which could possibly be arising from associative learning, will also impact social transmission.

Research Question

However, to understand how information is transmitted over social networks in the long term, we do not merely need to determine the process of the learner's choice of cultural variants to adopt; we also need to examine which cultural variants that learner transmits onward to others, a question that is extremely understudied: if a learner has acquired more than one variant of the same cultural trait (e.g., two different strategies to solve a problem) in different contexts – one from an expert and one from a peer – does that learner choose to transmit different variants in different onward transmission contexts (figure 1)?

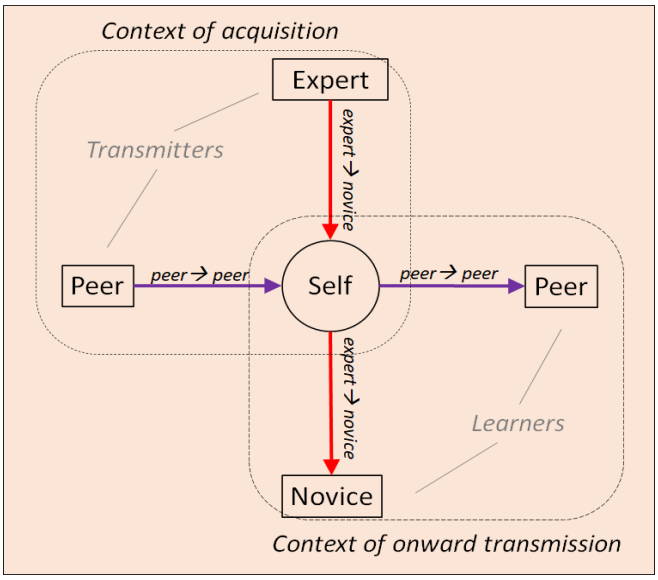

Figure 1: The social relationships between transmitters and learner (Expert→Novice / Peer→Peer) in the acquisition context, and between that learner and others (Expert→Novice / Peer→Peer) in the onward transmission context.

Objectives

We test whether the likelihood that a cultural variant is transmitted onward is affected by the social relationship between participant and learner during acquisition (Expert/Participant → Novice versus Peer/Participant → Peer).

To test this, we have created a novel experimental design. We manipulate the context of acquisition by introducing two variants of the same trait to each participant; one is introduced by the Expert (who represents a vertical transmission pathway), and the other by a Peer (who represents the horizontal transmission pathway). We also manipulate the context of the onward transmission by providing the participant with a learner of a specified identity – either a Novice or a Peer – to whom he/she is asked to transmit the trait.

As we include two different strategies in our experiment, there are two confounding variables which could affect what our participants transmit onward: (i) the strategy itself – as per Boyd and Richerson's (1985) content bias (see above) – and (ii) the order in which the two strategies are acquired by the participant. The order of acquisition has been previously shown to affect learning, by confirming the existence of a primacy and a recency effect (Tan & Ward, 2000; Merriman, Rovee-Collier, & Wilk, 1997; Wright, Santiago, Sands, Kendrick, & Cook, 1985; Anderson, 1965 etc.). For instance, the ability to recall brand names is more strongly affected by primacy than by recency (Li, 2010), as is the ability to learn the attributes of a repeated stimulus (Digirolamo & Hintzman, 1997). Therefore, we counterbalance both the variant of strategy that is transmitted to the participants (see methodology) and the order in which the strategies are learned, to control for the effects of primacy and recency.

Hypotheses

We expect that a model-based vertical bias will affect what our participants transmit onwards. Specifically, they will be more inclined to transmit the Expert's strategy, regardless of whether they are transmitting to a novice or to a peer.

In addition to that, we also expect that the context of onward transmission will have an effect on the choice of transmitted strategy by the participants: when asked to transmit to a peer, participants will be most likely to transmit the strategy they had acquired by a peer themselves, and, when asked to transmit to a novice, participants will be most likely to transmit the strategy they had acquired by an expert; so, we expect that a congruence bias will impact transmission. That congruence bias could, possibly, be connected with associative learning (Pavlov, 1927;

Bichler, Zhao, Alibart, Pleutin, Lenfant, Vuillaume, & Gamrat, 2013 etc.), with our participants connecting two events, of which one refers to, signals, co-occurs with or causes the other (Molchan, Sunderland, McIntosh, Herscovitch, & Schreurs, 1994; Shanks & Darby, 1998; Grillon, 2002; Mitchell, De Houwer, & Lovibond, 2009). Specifically, we expect that participants will associate the context of acquisition of a trait (i.e., from an expert of from a peer) with the context in which they transmit that trait onward (i.e., to a novice or to another peer respectively).

2 Methods

This study obtained ethical approval from Heriot-Watt University's School of Social Sciences ethical committee, and it was pre-registered with the Open Science Foundation.

2.1 Participants

Sixty-four adults (33 female; ages 18-28, M=21.17, SD=2.19) were recruited at Heriot Watt University in Edinburgh. These were students whom the experimenter approached in the Unversity's cafeterias and asked whether they would be interested in participating in a short experiment. She also posted notices about the experiment around campus, asking students to participate.

Five female psychology students of ages 19-21 (two in their second year, one in her third year and two in their final year) collaborated as the confederates for the experiment.

All participants were entered in a raffle to win one of two Amazon Vouchers worth £25. In addition, Psychology undergraduate students received credit for their participation.

2.2 Materials

2.2.1 Task

Using geargenerator.com, we created a sequence of seven gears, connected to one another. The task was to predict the direction (clockwise or anti-clockwise) in which the last gear in the sequence would turn, if the first one turned clockwise. We created and used this task because it was simple, and it has two alternative solutions that are equally costly and efficient in time and effort.

The gear sequence was presented on the computer's screen and the participants witnessed it as they entered the lab (as presented in figure 2 below). All participants saw the gear sequence frozen at first. The last gear of the sequence was a different colour than the rest, as it would become the focus of the problem later given to the participants.

This was a simple task with two alternative strategies that are equally costly and efficient.

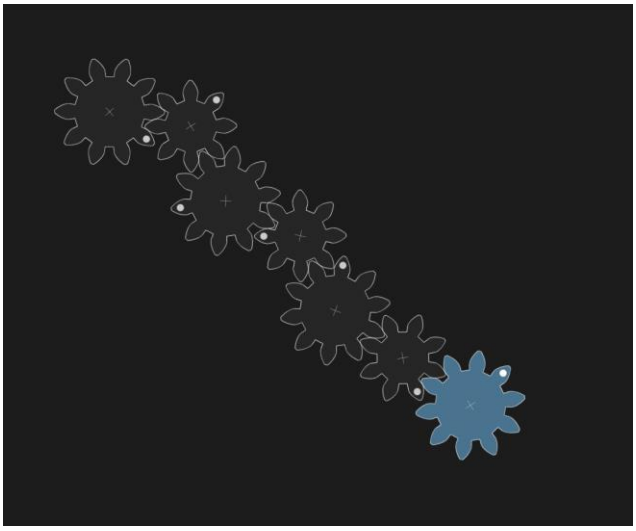

Figure 2: The sequence of the seven gears as they appeared on the computer screen.

2.2.2 Problem and Strategies to solving it

All participants were given the same problem to solve: "if we know that the first gear turns clockwise, which way does the last gear turn?". Following that, the experimenter (expert) and the first confederate (peer) verbally described to the participant two different strategies (one each) to solve the problem:

Strategy A: Counting the gears. The experimenter and the confederates provided the following descriptions: "First, you count all the gears. If we have an even number of gears, then the last gear will turn in the opposite direction from the first. If we have an odd number of gears, then the last gear and the first gear turn in the same direction".

Strategy B: Alternate directions. The experimenter and the confederates provided the following descriptions: "You can go clockwise, anticlockwise, clockwise, anticlockwise… clockwise".

All participants saw the same sequence of seven gears, in which the last gear turned clockwise.

This task was selected to control for content bias. The two solutions seemed equivalent in difficulty, and they took the same time to complete.

2.3 Design

For the purposes of this study, we have associated the verb "to teach" with the status of the *expert*, who transmits to a *novice*, and we have associated "to show" with the status of a *peer* who transmits to another *peer*. This terminology was used with our participants, and it is also used throughout this paper.

Each participant was assigned to one of two main conditions:
(i) in Condition 1, participants were asked to *teach* a *novice* (one of the confederates) how to solve the same problem that was presented to themselves, and
(ii) in Condition 2, participants were asked to *show* a *peer* (one of the confederates) how to solve the same problem. Each condition consisted of thirty-two participants.

The experimental design is summarised in Figure 2 below. Full counterbalancing meant that out of our 64 participants: 16 were first taught strategy A by an expert and subsequently shown strategy B by a peer; 16 were first taught strategy B by an expert and subsequently shown strategy A by a peer; 16 were first shown strategy B by a peer and subsequently taught strategy A by an expert; and 16 were first shown strategy A by a peer and subsequently taught strategy B by an expert (see Appendix D).

<table>
<tr><th colspan="3">Phase 1: Acquisition
(All participants trained in both contexts*)</th><th>Phase 2: Onward Transmission
(1/2 participants tested in each context)</th></tr>
<tr><td>Expert teaches
participant
(who is a novice)
Strategy A or B</td><td>AND</td><td>Peer shows
Participant
(who is a peer)
Strategy B or A</td><td>Participant (who is an expert)
teaches strategy to a novice
OR
Participant (who is a peer)
Shows strategy to another peer</td></tr>
<tr><td colspan="4">*Order (Expert-to-Novice, Peer-to-Peer) and Strategy (A, B) were fully counterbalanced.</td></tr>
</table>

Figure 2. Experimental design: First, participants were trained by an expert and by a peer on strategy A and strategy B. Then, for the testing phase, participants were told either they were now an expert and had to teach a novice how to solve the gear task (expert-to-novice condition) or that they now had to show another peer (peer-to-peer condition) how to solve the gear task. The 'expert' (underlined) was the experimenter (author AP) and the underlined 'novice' and 'peers' were three different confederates (fellow students). The dependent variable was the strategy produced in the context of onward transmission, either the strategy that was taught by a novice in the context of acquisition or the strategy that was shown by a peer.

2.4 Procedure

The experimenter led each participant in the building where the testing lab was and they headed together to the waiting area, where the first of her confederates (C1) waited. To establish a peer-peer relationship with the participant, C1 pretended to be another participant to the experiment. The experimenter introduced the participant to C1, explaining that she would pair up the two of them, as the experiment would be done in pairs. Then, she led both of them to the testing lab.

Both the participant and C1 were asked to fill in a consent form. After that, the experimenter provided the following instructions: "I will present you with a problem and then I will teach you the solution. If you look at the computer screen, you'll see some gears connected to each other and (hits "play") move each other. Now see, the first gear turns clockwise. (Hits "stop") The problem is to figure out which way the last gear of the sequence turns". After that, one of the following dialogues occurred, according to the condition in which the participant was assigned:

Expert's strategy first, participant teaches novice:

Phase 1: Acquisition

Experimenter – I will teach you the solution I've taught many people before as part of my experiment. [Teaches strategy].

C1 (Peer) – I've played this before, I know another solution. [Shows alternative strategy].

Experimenter – [Initiates Phase 2]: Oh okay, that's interesting! So now you both know two different solutions to this problem. Okay, for the next part I need you both to teach your solution to two other participants who don't know how to solve the problem, yet. So, I'll need one of you in this lab and the other one to the other lab. Who would like to come with me to the other lab?

C1 (Peer)– I'll come.

The experimenter leads C1 out and, after approximately ten seconds, brings in a different confederate (C2): the novice.

Phase 2: Onward Transmission

Experimenter – (looks at C2) Okay so, the problem is to figure out which way the last gear turns… [Participant] is now an expert at this, and he/she will now teach you his/her solution to the problem.

Peer's strategy first, participant teaches novice:

Phase 1: Acquisition

C1 (Peer) – I've played this before, I know a solution. [Shows strategy].

Experimenter – Oh okay, that's interesting! I will also teach you the solution I've taught many people before as part of my experiment. [Teaches alternative strategy, then initiates Phase 2].

The experimenter leads C1 out and, after approximately ten seconds, brings in a different confederate (C2): the novice.

Phase 2: Onward Transmission

Experimenter – (looks at C2) Okay so, the problem is to figure out which way the last gear turns… [Participant] is now an expert at this, and he/she will now teach you his/her solution to the problem.

Expert's strategy first, participant shows to peer:

Phase 1: Acquisition

Experimenter – I will teach you the solution I've taught many people before as part of my experiment. [Teaches strategy].

C1 (Peer) – I've played this before, I know another solution. [Shows alternative strategy].

Experimenter – [Initiates Phase 2]

The experimenter leads C1 out and, after approximately ten seconds, brings in a different confederate (C2): the peer.

Phase 2: Onward Transmission

Experimenter – (looks at C2) Okay so, the problem is to figure out which way the last gear turns… [Participant] is a participant just like you, and he/she will show you his/her solution to the problem.

Peer's strategy first, participant shows to peer:

Phase 1: Acquisition

C1 (Peer) – I've played this before, I know a solution. [Shows strategy].

Experimenter – Oh okay, that's interesting! I will also teach you the solution I've taught many people before as part of my experiment. [Teaches alternative strategy, then initiates Phase 2].

The experimenter leads C1 out and, after approximately ten seconds, brings in a different confederate (C2): the peer.

Phase 2: Onward Transmission

Experimenter – (looks at C2) Okay so, the problem is to figure out which way the last gear turns… [Participant] is a participant just like you, and he/she will show you his/her solution to the problem.

Following the above, the experimenter left the room. After approximately another thirty seconds (and after making sure that each participant had finished teaching/showing their solution without being seen), she went back inside, and she asked C2 to go back to the waiting area (from where she supposedly brought them) for a few minutes and wait to be debriefed. The confederate would, then, leave and note the solution that the participant chose to pass on (so that they could inform the experimenter after the participant left).

Then, she asked the participants a series of questions, to check whether they had realised the design of the study (i.e., that C1 and C2 were her confederates):

1. Why did you teach/show that solution?
2. What did you think happened in this experiment?
3. What did you think of the people who were with you in this experiment?

Finally, the experimenter debriefed the participants (explaining the design of the study and its aims) and thanked them for their participation in the experiment.

2.5 Coding

For each participant, we coded their ID, gender and age, and the following variables:

V1. Control factor 1. Order of strategies (A first / B first)
V2. Control factor 2. Order of acquisition contexts (Expert first / Peer first)
V3. Factor: Context of onward transmission (Expert-to-Novice / Peer-to-Peer)
V4. Dependent variable: Strategy transmitted onward by participant (Expert's / Peer's).

2.6 Analysis

To confirm that the strategy variant and the order of acquisition (controlled; see design) were not associated with the transmitted variant (Expert's/Peer's) by each participant, we conducted two Chi-squared tests of independence.

To test the effects of our factor variable on the transmitted strategy, we constructed a generalised linear mixed effects model (binomial family) using R (R Core Team, 2012). The model was fit using glmer from the lme4 package (Bates, Maechler, & Bolker, 2012; Bates et al., 2015) and the bobyqa optimiser. The dependent variable was the transmitted variant (Expert's / Peer's); the fixed effect was the context of onward transmission (Expert → Novice / Peer → Peer), and we included random intercepts for participant and gender (all the confederates and the experimenter were female and, therefore, gender was a confounding variable in our experiment). The full model (Transmitted variant ~ Context of onward transmission + (1 | Participant) + (1 | Gender) was tested against the null model, which contained only the random effects, using the anova() function.

3 Results

Two male participants (both from condition 1.a.; see Design) were excluded from the analysis, as the post-test questionnaire revealed they suspected the presence of confederates. No other participants suspected this.

The Chi-squared tests of independence indicated that strategy variant (A or B) was not associated with the transmitted variant (Expert's/Peer's), χ^2 (1, N=62) = 0.13, p >0, and neither was the order of acquisition (first form Expert / first from Peer), χ^2 (1, N=62) = 0.52, p >0.1.

3.1 Descriptive Results

Across conditions, the Expert's strategy was produced significantly more often overall (N=41) (Figure 4) than the strategy acquired from a peer (N=21) (χ2=9.00, df=2, p<0.05). However, in the Peer → Peer context of onward transmission, there was an increase in the transmission of the Peer's variant (Table 2).

Context of Onward Transmission	Variant Transmitted onward	
	Expert's Strategy	Peer's Strategy
Expert → Novice (N=30)	90%	10%
Peer → Peer (N=32)	43.8%	56.3%
Total	66.1%	33.9%

Table 2: Proportion of transmitted variant grouped by the social relationship of participant (i.e., transmitter) and learner.

3.2 GLMER

The full model containing the fixed effects (context of acquisition and context of onward transmission) was significantly better than the null model (χ2=16.02, df=1, p<0.001) (Table 3).

Model: Context of acquisition + (1 | Participant) + (1 | Gender)				
	Estimate	SE	*z*-value	*p*-value
Context of Onward Transmission (Peer → Peer)	2.45	0.71	3.45	<0.001***
Marginal R^2: 0.31, Conditional R^2: 0.31				

Table 3: Summary of our full GLMER model.

The context of onward transmission significantly affected the participants' choice of which variant to transmit, with those in the Peer → Peer condition being more likely to transmit onward the Peer's variant (Figure 4).

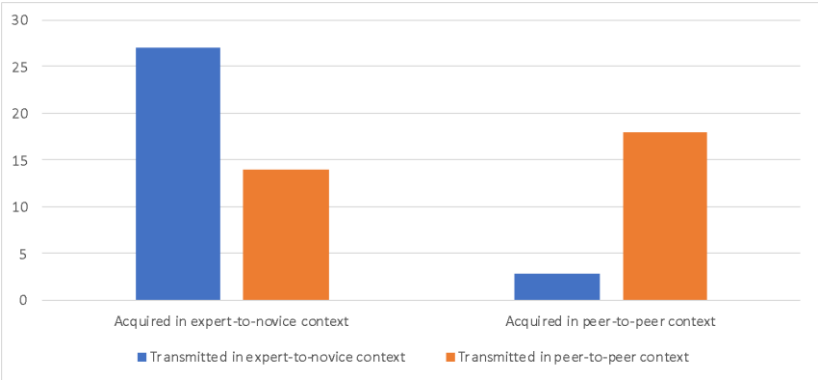

Figure 4: Number of each variant of strategy produced by acquisition context and onward transmission context.

Congruent results – in which the variant acquired from an expert was taught to a novice or the variant acquired from a peer was shown to another peer (N=45) – were significantly more frequent than instances in which the variant acquired from an expert was shown to a peer or the variant acquired from a peer was taught to a novice (N=17) ($\chi 2=18.95$, df=2, $p<0.001$) (leftmost and rightmost bars in figure 4).

4 Discussion

The main objective of this study was to examine how the contexts of acquisition and onward transmission affect what transmitters choose to pass on to learners. Two models – an expert and a peer – transmitted each a different strategy to solving a problem to every participant. Each participant transmitted onward only one of the strategies. As our analysis demonstrates, content-based bias was successfully controlled for (i.e., the effect of the strategy variant was null in our experiment). We measured how often each strategy was transmitted onward by the participants and we investigated whether their choice was affected by the participant → learner relationship (Expert → Novice / Peer → Peer). Our results yield three major conclusions, which are discussed below.

4.1 Model-based Bias

As expected, participants overall tended to transmit onward the Expert's variant. We, therefore, suggest that – in accordance with previous studies (Wood et al., 2016; McGuigan, 2013; Atkisson, O'Brien & Mesoudi, 2012; Seehagen & Herbert, 2011; Jaswal & Neely, 2006) – a model-based *vertical* bias affected transmission, with the Expert being the transmitter whose strategy was more likely to be transmitted onward than the Peer's strategy.

Generally, the model-based bias (Boyd & Richerson, 1985; see also Henrich & McElreath, 2003) posits that the likelihood of a learner copying one variant over its competing one(s) is affected by the specific attributes of the model/transmitter who exhibits that variant (Brannen, 1995; Sperber & Claidière, 2008; Wood, Kendal, & Flynn, 2012, 2013). It has previously been shown that such attributes include perceived skill and knowledge (Henrich & Gil-White, 2001; Reyes-Garcia et al., 2008). The experimenter – i.e., the Expert model in our design – explicitly displayed these attributes, by presenting herself as the "teacher" who has "taught many people before" in "her" experiment. In contrast the Peer model (C1) and learner (C2) were presented as another participant about to learn something and "a participant just like" the participants themselves respectively, in order to reinforce the perceived homophily and equality in skill and knowledge.

4.2 Associative Learning and Context-congruence bias

Our study shows that learners do not copy experts unconditionally; in the context of a Peer → Peer relationship, participants transmitted onward the strategy acquired from another Peer significantly more often than when having an Expert → Novice. As this tendency cannot be attributed to a model-based horizontal bias – because only a small fraction of our participants in the Expert → Novice transmission context transmitted onward the Peer's strategy (figure 4) – we suggest that there exists another factor which impacts social transmission.

Our results suggest that, in addition to model-based bias, a context-congruence bias operates on transmission. In the context of onward transmission to a peer, we tend to pass variants learned in a peer-to-peer acquisition context, while in the context of onward transmission to a novice, we tend to pass variants learned in an expert-to-novice acquisition context (Fig. 1). So, the relevant feature of the transmitter, which affects social transmission, is his/her *relationship* with the learner – as formed by the context of onward transmission – and not simply the

attributes of the transmitter during acquisition (Boyd & Richerson, 1985), such as expertise and knowledge (Henrich & Gil-White, 2001), or familiarity and homophily (Zmyj et al., 2012).

When the learner is a perceived novice, an Expert → Novice relationship is formed. During this, it is possible that the expert-transmitter associates the cultural variant acquired from another expert with the cultural variant deemed best to transmit onward to the novice-learner. Accordingly, when the learner is a perceived peer, a Peer → Peer relationship is formed, and the peer-transmitter associates the cultural variant he/she had acquired from another peer with the cultural variant deemed best to transmit onward to the peer-learner. We can then infer that the participants could be learning to associate variants with transmitter-receiver relationships during transmission (Molchan et al, 1994; Shanks & Darby, 1998; Grillon, 2002), with our participants/transmitters associating the cultural variant deemed best to be transmitted onward, with the context in which they had acquired that variant themselves (Mitchell, De Houwer, & Lovibond, 2009): from an Expert or from a Peer. We hypothesise, therefore, that associative learning maybe linked to the context-congruence bias observed (perceived Experts transmit the Expert's variant to novices and perceived Peers transmit the Peer's variant to peers). As this is the first instance in which the two are linked, we suggest that this hypothesis be followed up in future work.

Although previous studies have also demonstrated the intergenerational congruence of traits during vertical – e.g., parent-to-child (Card & Giuliano, 2013; Kassarnig et al., 2017; de Paola, 2010), and horizontal transmission – i.e., peer-to-peer (Weerman & Smeenk, 2005; Young, Rebellon, Barnes, & Weerman, 2014), the cognitive processes in operation leading to that congruence had not been sufficiently explored. This might be due to the narrower scope of focus of social transmission studies, which attempts to answer questions such as how the behaviour of peers affects the behaviour of participants (Albert & Ferring, 2012), or how the closeness of a parent and child affects their behavioural congruence (Euler, Hoier, & Rohde, 2001; Hayden, Singer, & Chrisler, 2006; Lefkowitz & Fingerman, 2003).

In our study, we have widened that scope, by examining how relationships between the contexts of acquisition and onward transmission affect the social transmission of cultural traits. This illustrates the possible impact of associative learning in social transmission and the resulting congruence between transmitted behaviour in acquisition and transmitted behaviour in onward transmission.

4.3 Biases on Onward Transmission

In turn, then, we have shown evidence for the first factor which affects not only the adoption of behaviour by a learner, but, also, the *onward* social transmission of said behaviour by that learner: the context-congruence bias. This has important implications for cultural evolution, as it explains the continuity of vertical transmission of traits and their subsequent conservation (Cavalli-Sforza et al., 1982), and the lower continuity of horizontal transmission of traits and the fast cultural changes to which this can lead (Acerbi & Parisi, 2006).

The context-congruence bias we found entrenches the reliance of cultural variants on a particular transmission pathway .So, we can infer that the parents' tendency to transmit to their children – the learners at time A – their political orientations (Boehnke & Schiefer, 2016; Nesi, Choukas-Bradley, & Prinstein, 2018) will lead to the children's tendency to transmit onward the same orientations to their children independently of whether they acquire different ideologies from their peers in the meantime. By extension, we can assume that all traits – including gender ideology, religious values, academic values and so on – previously found to be transmitted from parent to child (Cavalli-Sforza et al., 1982; Dalhouse & Frideres, 1996; Jodl et al., 2001; Miller & Glass, 1989; Vollebergh, Iedema, & Raaijmakers, 2001), will continue to follow that same vertical pathway, thus conserving such traits for many generations to come (Tomasello, 2009; Caldwell & Millen, 2008; Mesoudi & Whiten, 2008).

Similarly, traits which were found to be horizontally transmitted (from peer to peer) will also continue to follow the analogous pathway. Despite only guaranteeing the persistence of behaviours for a maximum of one cultural generation, horizontal transmission can lead to vast cultural change (Cavalli-Sforza, & Feldman, 1981; Cavalli-Sforza et al., 1982, Tomasello, 2009; Caldwell & Millen, 2008; Mesoudi & Whiten, 2008; Boyd & Richerson, 1996; Rubin, 1995), especially in the Information Age. The context-congruence bias could be operating behind the increasing peer-to-peer transmission of traits through social media (Bennett & Livingston, 2018; Farhall, Carson, Wright, Gibbons, & Lukamto, 2019; Shimizu, 2020). This would explain the continuity of transmitting maladaptive traits such as fake news and disinformation (Euler et al., 2001; Hayden et al., 2006; Lefkowitz & Fingerman, 2003). More importantly, it could be the key to identifying ways of tackling problems arising from such phenomena, such as the worsening of disease outbreaks (Brainard & Hunter, 2020; Tagliabue, Galassi, & Mariani, 2020) and the flourishing of racist attitudes (Cleland, 2014; Shimizu, 2020).

The context-congruence bias we have revealed may affect long-term cultural evolution. In the extreme, many of the cultural variants that are learned horizontally, among age-peers, could be locked in a particular generation and die out with it (an example of this are slang words that characterise a generation; see Zhou & Fan, 2013), and variants that are transmitted vertically could be very long-lasting as they would be preserved over generations. Knowing which variant of cultural variants tend to be passed on from parents to children or among peers, therefore, is one of the factors we should take into consideration when aiming to predict the cultural fate of those variants. Cavalli-Sforza et al. (1982) found, for example, that religion tends to be passed on from mother to child, political ideology from father to child, while social skills tend to be transmitted between peers (Adler, Kless, & Adler, 1992); knowing the strength of these effects could be used to fit parameterised evolutionary models and help predict the longevity of cultural traits.

4.4 Experimental design issues and recommendations for future work

Our experiment used a complex design, part of which was the creation of three cultural generations. We needed our participants to believe that only the experimenter was part of the procedure and that the confederates acting as transmitters (exhibiting the Peer's strategy to the participant) and learners (assuming either the role of a novice or a peer in relation to the participant) were co-participants to the experiment. By asking indirectly after the completion of the experiment (e.g., "what do you think is the aim of this experiment", "how do you think your knowledge has increased", "how do you think the knowledge of the other people who worked with you has increased", "did you teach someone something new" etc.), we found out that two of our sixty-four participants had suspected that the two confederates they saw each time were, in fact, part of the experiment and that they were working with the experimenter.

Although none of the remaining participants appeared to have realised the presence of confederates, one could argue that we cannot expect that the transmitter-confederate was someone with whom the participants would associate to the point that they felt she was their peer. Her additional knowledge regarding the experiment may have hindered somewhat the participant's ability to see her as their peer. In a real-world paradigm, however, a learner acquires cultural information from a peer-transmitter who, therefore, possesses knowledge which the learner does not. Yet, the transmitter will still be identifiable as a peer, albeit being more knowledgeable. Thus, in our study, the difference of knowledge in our participants and

the confederates does not impede their perceiving the confederates as similar to themselves, or their associating the Peer's strategy with the one deemed best to transmit onward to them. Nevertheless, even with this potential limitation, we observed a context-congruence bias. So, in the case of real peers and real experts, the effect would be stronger.

The participants' perception of their knowledge status in relation to their perception of the transmitter's and the learner's knowledge statuses was an essential tool in our design. As such, when participants were introduced to the "novice", the experimenter referred to them as "experts to facilitate the perception of their difference in knowledge/expertise, and when introduced to the "peer", the experimenter referred to that confederate as "another participant just like you", to strengthen the perception of homophily. However, it would be difficult to ascertain the dynamics of the participant → learner relationship during onward transmission, as we had no way of measuring the increase or decrease in perceived expertise and/or homophily. Despite that, we assume that the participants experienced analogous situations in their everyday lives, in which they felt "experts" (e.g., when teaching a younger cousin how to win at a game or teaching a sibling how to solve their math problem etc.) and "peers" in relation to others (e.g., when helping a classmate with homework, when showing a friend how to play a game they like etc.). In these situations, their perceived role as transmitters was not always apparent (as in our experiment), but it was implied.

Although our study provided evidence for the context-congruence bias of transmitter and learner relationship as formed by expertise versus homophily, other characteristics could also be shaping this relationship during acquisition and onward transmission.

For instance, it is a consensus in the literature that mothers and daughters share higher levels of behavioural and attitude concordance than do mothers and sons or fathers and daughters (Euler et al., 2001; Hayden et al., 2006; Lefkowitz & Fingerman, 2003). Gender could, then, be another extension of the transmitter-learner relationship which leads to congruency in their choice of trait transmission. In our study, all the transmitters during acquisition (i.e., the experimenter and the confederates), as well as the learners during onward transmission (confederates) were female, so we could not test for a gender congruence, though it would be an interesting aspect which future research could investigate. Other characteristics which should be explored as they could be significantly affecting the relationship between transmitters and learners can include race (Gershenson, Hart, Hyman, Lindsay, & Papageorge, 2018; Hoxby, 2000) and social class (Condron, 2009). In general, there could be multiple

dimensions of the context whose congruency could affect transmission including place, time of day, time of year, and language spoken (for multilingual individuals) among many others.

Finally, our study may have shown that the model-based and context-congruence biases interact with each other. An interesting next step would be to examine how these interactions occur with different actors (e.g., mothers, fathers, teachers, peers, experts) at different ages and for different cultural traits.

4.5 Conclusions

In summary, we have shown evidence for a cultural transmission bias that links acquisition and onward transmission. Cultural variants are more likely to be passed on if aspects of the current context were also present in the context in which the variant was acquired. In particular, the contextual aspect we have focused on is the relationship between transmitter and receiver of information. If we learn different variants of a trait from a peer and an expert, we tend to transmit the former to other peers and the latter to when we become experts. Extending beyond our study, the context-congruence bias could, possibly, affect the conservation of cultural traits which often appear to be transmitted vertically from parent to child within a population – such as language, religion, tradition, and habits– as well as the likelihood that, such traits, will continue to follow a vertical pathway of transmission. In parallel, the context-congruence bias is one of the factors that can be used to explain the cultural change brought forth by the transmission of traits from peer to peer, as transmitters could be likely to continue to pass on their horizontally acquired knowledge to other learners – given these learners are perceived peers – using means which enable and support fast horizontal transmission, such as social media.

Our findings contribute important new knowledge to cultural evolutionary theory, as we can suggest that the previously studied and confirmed cognitive biases operating during the *acquisition* of cultural information by learners, should be altered to account for the *onward* transmission of said information, as well. As such, we may be able to gain a better understanding of some of the mechanisms behind cultural transmission. This is necessary to ensure the conservation of target traits and behaviour, and to intercept and disrupt the transmission of maladaptive information, such as political extremities, disinformation, and inequality.

Chapter 4

Understanding Cultural Information Flow: A Qualitative study of a small social group

Abstract

This study uses qualitative data to explore closely adoption and onward transmission. Participants were asked questions on the subject of housework, and they provided interview data regarding the perceived behaviour of their parents, of themselves, and of their (grand)children. Observational data was also collected from the members of one family in their own houses for triangulation purposes. Following the six-phase process of thematic analysis, we extracted three main themes: individual learning, horizontal transmission, and vertical transmission. There were few instances categorised as 'individual learning'. In contrast, the instances of horizontal and vertical transmission were numerous, and they included the transmission of dichotomous traits. This allowed us to examine why some cultural variants outcompete others and how certain learning and teaching mechanisms lead to increased stability and longevity. One possible factor influencing the persistence of one variant over another was our proposed context-congruence bias (previous chapter). Vertical congruence was observed during the transmission of a dichotomous cultural trait: transmitters who acquired two variants of the same trait (one horizontally and one vertically) chose to vertically transmit onward to learners – i.e., their (grand)children – the variant which they had previously acquired vertically (i.e., from their own parents or grandparents), even if they exhibited both variants themselves. Horizontal congruence was observed even in sibling-to-sibling transmission, as the transmitter (older sibling) transmitted onward to the learner (younger sibling) the cultural variants which he/she had previously acquired from a peer (even if these were in competition with vertically acquired alternatives). Finally, we discuss the effects of the mother/wife-

transmitter, who can weaken the effects of the vertical-congruence bias in the case of her spouse and enhance them in the case of their children.

1 Literature Review

1.1 Cultural Transmission

Cultural transmission entails the communication of socially learned information – such as traits, behaviour, attitudes etc. – from one individual or group to another individual or group (Cavalli-Sforza & Feldman, 1981; Mesoudi & Whiten, 2008; Tomasello, 2001) and is, generally, evident in many species (Allen et al., 2013; Krützen et al., 2005; Lamon et al., 2017; Terkel, 1996). Yet, cumulative cultural transmission, which enables the formation of sophisticated products so complex that no one generation could invent on their own (Caldwell & Millen, 2008; Tennie et al., 2014; Tomasello, 1999), appears to be a uniquely human capacity (Dean et al., 2012, 2014; Kurzban & Barrett, 2012; Tennie, Call, & Tomasello, 2009; Tomasello, 2001; though see Davis, Vale, Schapiro, Lambeth, & Whiten, 2016.

In general, the causal, intentional and/or functional nature of cultural information is often cognitively opaque to new learners and current users alike (Gergely & Csibra, 2006). For instance, a learner may not understand why her mother brushes her hair before going to bed, why her older brother holds his spoon with one hand while pouring milk into his bowl of cereal with the other, why her friend sings while skipping rope etc. She may, also, not understand the causality of removing a seemingly irrelevant bolt on top of a transparent box when the goal is to get a reward from inside of a hole of it (Horner & Whiten, 2005).

Goal-oriented (emulative) learning mechanisms – such as the ones exhibited by non-human animals, including primates (Call, Carpenter, & Tomasello, 2005; Tomasello, 1996; Tomasello & Call, 1997) – are insufficient for the faithful transmission of said information, as the learners would not reproduce the elements which they perceive unnecessary or irrelevant to their goal, such as removing the irrelevant bolts to get to the reward inside a box (Horner & Whiten, 2005). Subsequently, such learning mechanisms are insufficient for cumulative cultural evolution (Acerbi, Tennie, & Nunn, 2011; Tennie, Call, & Tomasello, 2009).

The human capacity for high-fidelity imitation, however – which often extends to overimitation (i.e., the imitation of causally irrelevant components of the information transmitted to them; Clay & Tennie, 2018; Hoehl et al., 2019; Lyons, Young, & Keil, 2007; McGuigan, Makinson, & Whiten, 2011) – is one of the mechanisms which allow the conservation of the information

transmitted along generations and eliminate the costs of individual learning by trial and error (Mesoudi, 2008; Mesoudi & O'Brien, 2008). In parallel, humans are innovators: they add modifications and improvements upon the information transmitted to them and then they transmit onwards the new and, often, improved product (Boyd, Richerson, & Henrich, 2011) with high degrees of fidelity. As such, Legare and Nielsen (2015) refer to imitation and innovation as the dual engines enabling cumulative culture.

To understand the cumulative cultural transmission of information and its cumulative cultural evolution, studies have focused on different aspects, such as transmission mechanisms (Bisin & Verdier, 2000) and transmission modalities (Caldwell & Millen, 2009; Morgan et al., 2015; Putt, Woods, & Franciscus, 2014; Zwirner & Thornton, 2015). Moreover, Boyd and Richerson (1985) have proposed a set of biases, which underlie cultural transmission: (i) the content-based bias, according to which some of the intrinsic properties of a cultural trait (e.g., effectiveness, simplicity etc.) increase the likelihood that a learner will adopt it, (ii) frequency-based bias, according to which the likelihood that a learner adopts a trait is dependent upon how common that trait is in his/her social group, and (iii) model-based bias, which postulates that the specific characteristics of a transmitter (e.g., prestige, gender etc.) affect the probability that the learner will adopt his/her behaviour (Henrich, Boyd, & Richerson, 2008; Mesoudi, Whiten, & Dunbar, 2006; O'Gorman, Wilson, & Miller, 2008).

1.2 Pathways of Transmission

Previous studies have also focused on the different pathways of cultural transmission (Boyd & Richerson, 1985; Cavalli-Sforza & Feldman, 1981; Mesoudi & O'Brien, 2008). Unlike the biological transmission of genes, which can only follow a vertical pathway (from parent to child), cultural transmission can also follow a horizontal (from one individual or group to another individual or group of the same generation), an oblique (from an individual or group of a generation to another individual or group of the next generation), an indirect vertical pathway (from grandparent to grandchild) (Bengtson, Copen, Putney, & Silverstein, 2009; Lang & Randall, 2013; Pratt, Norris, Hebblethwaite, & Arnold, 2008), and, even, a reverse-

vertical pathway (from child to parent) (Allison, 1992; Cavalli-Sforza, 1986; Cavalli-Sforza & Feldman, 1981).

According to Cavalli-Sforza (1986), cultural transmission can work towards both very fast change and very high conservation. As horizontal transmission only guarantees the preservation of the transmitted information for one biological generation of learners (Cavalli-Sforza & Feldman, 1981), it is advantageous in rapidly changing environments (Schönpflug, 2001). Vertical transmission, on the other hand, allows the continuity and high conservation of the transmitted information for over two biological generations (Cavalli-Sforza et al., 1982; Garfield, Garfield, & Hewlett, 2016) and can yield products which are passed on for many more (Boyd & Richerson, 1995; Caldwell & Millen, 2008; Mesoudi & Whiten, 2008). Unlike biological transmission though, vertical cultural transmission of traits can be from just one parent to the child, e.g., from mother to daughter or from father to son (Al-Zu'bi, 2015; Campante & Yanagizawa-Drott, 2015; Davies & Fitchett, 2015).

Different transmission pathways are dominant during different stages of development (Henrich & Broesch, 2011; Henrich & Henrich, 2010; Hewlett et al., 2011). Vertical transmission is dominant during infancy and early childhood, when the child is in close proximity to her parents (Hewlett et al., 2000; Reyes-Garcia, Gallois, & Demps, 2016), while horizontal and oblique transmission are dominant later on (Hewlett et al., 2011). In fact, Reyes-Garcia and colleagues (2016) suggest that oblique transmission occurs in adulthood and can update the knowledge the learner had acquired via vertical and horizontal transmission earlier in life.

Naturally, then, different pathways of transmission are associated with different forms of cultural information. For instance, complex information such as political tendencies, religion, superstitions and beliefs, customs and habits tend to be passed on vertically from parent(s) to child (Cavalli-Sforza et al., 1982), while career and social mobility, aspirations, sex-role and sexual behaviour (Schönpflug, 2001), eating behaviours (Baker, Little, & Brownell, 2003; Maximova et al., 2008) and social skills (Adler, Kless, & Adler, 1992) are transmitted horizontally and obliquely.

Previous studies have shown that the vertical pathway of transmission leads to intergenerational congruence (Dalhouse & Frideres, 1996; Miller & Glass, 1989; Vollebergh, Iedema, & Raaijmakers, 2001), with two biological generations (e.g., father and son, father and daughter etc.) displaying similar or, even, the same cultural traits (e.g., political tendencies). This is also the case for horizontal transmission, as two consecutive cultural generations – i.e.,

a peer-transmitter and a peer-learner – show behavioural congruence (Card & Giuliano, 2013; Cheng & Chartrand, 2003; Kassarnig, Bjerre-Nielsen, Mones, Lehmann, & Lassen, 2017; de Paola, 2010; Yabar, Johnston, Miles, & Peace, 2006). In chapter 3, we have extended the above studies to examine onward transmission and we found that participants were significantly more likely to vertically transmit the variants which they had acquired vertically and horizontally those that they had acquired horizontally. Our results suggest that a context-congruence bias affects cultural transmission and that, due to this, cultural information will adhere significantly often to following the same pathway of transmission (vertical or horizontal).

In summary, new learners acquire complex cultural information from their parents first, and then, they acquire cultural information from their peers as soon as they start socialising outside the household. Finally, when they enter school, university and so on, they acquire information obliquely from teachers, experts etc (for examples of oblique transmission in hunter-gatherer societies see Guglielmino et al., 1995; Henrich & Broesch, 2011; Kline, 2013; Lancy, 2012). Additionally, transmission biases will affect the learners' choice of which variants to adopt for themselves (Boyd & Richerson, 1985; Mesoudi et al., 2006). However, we still do not know what happens when those learners start transmitting onward information to others and, especially, to their children. Though in Chapter 3 we have taken the first step in empirically examining onward transmission, our participants' roles were limited to those of peer versus expert/novice. Yet, as shown from studies with parents and their children (see above), the parents can be the most influential vertical transmitters of certain cultural traits. Currently, we do not know what learners will choose to transmit onward when they become parents, though. Specifically, do they "revert" back and transmit to their children the information passed down to them from their parents – as per the context-congruence bias (Chapter 3), or do they transmit the information updated or, even, substituted (Reyes-Garcia et al., 2016) with knowledge gained from peers and experts later in life?

To answer such questions, we need to examine the cultural transmission of information with social networks which include both successive generations (e.g., parents and their children) and agents of horizontal transmission (e.g., friends, siblings etc.). We also need to extract information regarding the cultural transmission of specific traits, which can be passed on both vertically and horizontally.

1.3 Cultural Transmission of Housework

As cultural information has been found to manifest in housework (Fernández, Fogli, & Olivetti, 2004), chores and related activities could provide useful insights regarding how information is transmitted over generations vertically (e.g., from parent-to-child) and horizontally (e.g., sibling-to-sibling, spouse-to-spouse etc.). In general, housework is a subject with which most individuals have experience; most people – and, more likely, everyone – have either done housework, have received instructions/teaching on how to do housework or, at the very least, have observed a member of their household doing housework in the past.

We, therefore, chose to focus on it for our study, expecting that it would be easy for individuals to discuss and provide information about their own behaviour and that of others in their household, as they will all have had some form of experience with it. Moreover, housework is associated with many distinct cultural traits: from chores – such as cooking, sweeping, mopping etc. – to attitudes, such as gender roles and member-specific roles (e.g., the "mother's" or the "father's" responsibilities), so we expected a large array of distinct behaviours to be evident in our data. For instance, Gergely and Csibra (2006) describe the high-fidelity vertical transmission of cooking behaviour from mother to daughter, with the daughter, Sylvia, executing all the steps she had observed her mother do while cooking ham, including the causally opaque step of cutting its end sections. Years later, the mother explained that she had performed this step because, contrary to Sylvia, she did not own a pan large enough to fit the whole ham. Sylvia had continued to perform that step, without ever doubting its functionality, because that was the way her mother "always began with a ham." (p. 6).

We also expect our data to reflect our participants' attitudes towards housework, as studies have argued that household participation attitudes (and not merely the observed behaviours) can be transmitted vertically (Fernández et al., 2004; Thornton, Alwin, & Camburn, 1983) and they reflect the gendered division of labour (Reyes-Garcia et al., 2016). In fact, gender has been found to affect social learning, with girls, for instance, imitating their mothers while doing housework more closely than boys imitate their fathers (Lancy, 2012). However, it has also been argued that, upon socialising with their peers, children will participate in play forms which are related to the gender-specific tasks – such as pretend-cleaning – they will be expected to execute later in life (Bock & Johnson, 2004) and, so, we expect that gender-specific roles would also be transmitted horizontally as has been previously argued (Schönpflug, 2001). Therefore, we expect that our study will help us examine whether information gained later in life (horizontally or obliquely) can replace vertically acquired variants and, whether the learners

transmit onward the newly-gained information, or the information acquired from, e.g., their parents.

1.4 Aims and Objectives

Presently, onward transmission is extremely understudied. Yet, to understand the cultural evolution of information, it is necessary to examine the entire process of cultural transmission: from what is adopted by a learner (which has been the focus of previous studies) to what is transmitted onwards by that learner. The current study will aim to identify whose behaviours and attitudes (parent's, siblings', grandparents', friends') people tend to adopt for themselves – i.e., the vertically transmitted traits during socialising in the home (e.g., the parents') or the horizontally transmitted ones during socialising inside (e.g., siblings) and/or outside the home (e.g., friends). In parallel, we aim to identify what people transmit onward to others (their children, friends etc.), and aid our understanding of the onward transmission process.

To examine closely both adoption and onward transmission, we conducted a qualitative study, in which we recruited the members of three different biological generations within the same family (from grandmother to grandchildren). We have recruited the maternal grandmother (from here on: "Grandmother A") and her daughter ("Mother A"), as the literature suggests a stronger mother-daughter bond than mother-son, father-son and father-daughter (Euler, Hoier, & Rohde, 2001a; Hayden, Singer, & Chrisler, 2006; Lefkowitz & Fingerman, 2003); therefore, we expect higher conservation of vertically transmitted cultural traits within this social network than if we had recruited any other pair (mother-son, father-son and father-daughter). We also recruited her grandchildren (i.e., "Child 1", "2" and "3"), as there seems to be a stronger bond between the maternal grandmother with the grandchildren than the maternal grandfather or either of the paternal grandparents with the grandchildren (Eisenberg, 1988; Euler, Hoier, & Rohde, 2001b; Pollet, Nettle, & Nelissen, 2007). We also recruited Mother A's husband, as he is the Father (A) of the Children 1,2 and 3 and, therefore, an essential vertical transmitter to them.

Within this social network, we expected to discover three forms of vertical transmission of cultural information: (i) direct vertical (from parent to child), (ii) indirect vertical (from grandmother to grandchild) and (iii) reverse vertical (from child to parent). We also expected instances of horizontal transmission (between husband and wife, between friends of similar age and between siblings).

To complement the family's social network (see Figure 1 below), we also recruited peers (friends) of each of the members. This allowed us to examine how horizontally transmitted variants of the information might affect what the family members proceed to transmit onward to their children. For instance, if the father has learned from his father variant x of a certain trait and then, from one of his peers variant y of the same trait, will he transmit variant x or y to his children?

Three of the peers –the grandmother's, one of the mother's and one of the grandchildren's – also constituted three biological generations of a family (grandmother, mother, and granddaughter), which allowed us to compare the cultural information transmitted vertically and conserved between the two families. In a social network as complex as that of a family of three generations and their peers, we can expect that different variants of information have been transmitted through different pathways (Adler et al., 1992; Cavalli-Sforza et al., 1982).

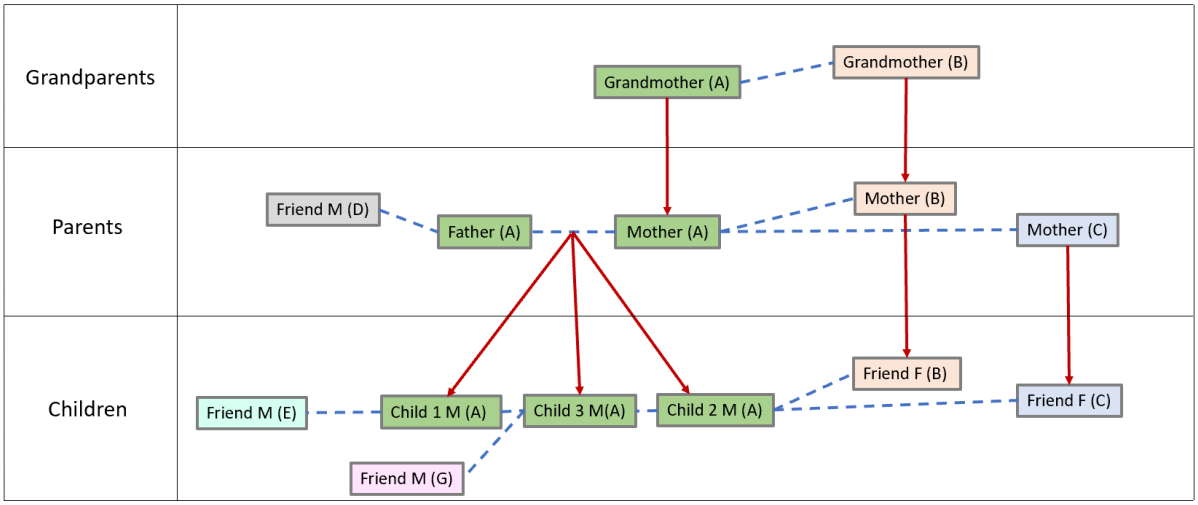

Figure 1: The social network of recruited participants. The red lines represent the vertical connection (parent-child) between participants of three different families (Family A, B and C), and the blue lines represent the horizontal connections (friends / siblings / spouses). The letters in the parentheses represent different families, and the "F" / "M" represent the gender of the participants. Though we have data about the great-grandparents A and B, they are not participants.

2 Methodology

The study obtained ethical approval from the Heriot-Watt University's School of Social Sciences ethical committee.

2.1 Participants

Fourteen participants (seven female, ages: 13-77, mean=38.36, SD=22.45) were recruited in total (figure 1). All fourteen participants gave their informed consent to take part (adults) or their parents' consent was obtained for their participation (non-adults). The participants all belonged to the first author's close social network. Mother A and Father A are her parents, and Children 1, 2 and 3 are her brothers.

Previous studies have demonstrated the research benefits from studying one's own family – mainly by employing self-ethnography (Vedder-Weiss, 2017) or auto-ethnography (Adams & Manning, 2015) as data collection methods. It should be noted that, though the current study adopts a self-ethnographic approach when the first author observes her family (members of Family A), the observations (see measure below) are conducted without her engagement with the participants or with their activities (Alvesson, 2003). The greatest advantages of self-ethnography to our study were the "natural access" (Alvesson, 2003; p. 174) that the first author had to the cultural setting (i.e., the family home), which allowed her to document the participants' behaviour as it happened, and her prior knowledge and pre-understanding of the context, which allowed her to "develop new understandings" (Vedder-Weiss, 2017; p. 357). Though self-ethnographic approaches can add an element of subjectivity (Butler, 2005), we believe that the above advantages, coupled with recording the interviews and examining the observational and interview data (which allowed data triangulation; see measures below) together, offer the opportunity to make valuable inferences based on the results.

For the data collection process, the first author stayed with her family in their home (as per usual during her visits to Cyprus), where she observed and interviewed them. The remaining participants, she recruited by visiting each one in their home, where the interviews took place. In her Grandmother's (A) home, from whom observational data was collected as well, she spent considerably more time than in the remaining participants' homes, though she only engaged with her Grandmother during the interviews.

The close relationship of the first author with the participants (family members and close acquaintances) benefitted this study. The observational data was collected without the participants feeling self-cautious or unsure of the actions they performed while being observed. In contrast, they were more likely to act as they naturally do than they would be with an unfamiliar researcher, because they were already comfortable having her in the same room as themselves. Due to this, she was able to document spontaneous, genuine behaviours. In addition, the previous familiarity of the participants with her encouraged them to express

themselves in a more comfortable manner during the interviews and share more details (such as anecdotes, habits etc.) which enriched the collected data. Finally, her close relationship with the participants allowed her to contact them after the interviews to clarify the meaning of some of their responses and ensure that she interpreted them correctly.

Our respondents included the Grandmother A (seventy-seven years old, widowed, pensioner), her daughter, i.e., Mother A (forty-nine years old, married, full-time nurse supervisor), and three of her grandchildren, i.e., Children 1 (male; twenty-five years old, full-time paramedic), 2 (male; seventeen years old, student) and 3 (male; thirteen years old, student). As some of our interview questions focus on behaviours transmitted to the participants from their parents, our data also includes some of the grandmother's subjective information regarding the behaviour of her parents (great-grandparents A). Each of the Children (A) served as a peer to one another, as did Father A (fifty-one years old, married, full-time bank employee) and Mother A to each other (see Figure 1 above).

We also recruited one of the Grandmother A's peers – Grandmother B (seventy-seven years old, widowed, pensioner). The two of them met after the turkish invasion of 1974, when they had to relocate to a non-invaded part of the country. Though originally from different cities, they have many similarities: they are of the same age, they were both born into very poor families, and they had both lost their fathers when they were young. Nonetheless, they both ended-up marrying men of significantly higher socio-economic status, which led to their entering a different way of life (e.g., they gained daily access to meat, they moved to bigger houses etc.). As young adults and recent mothers (Grandmother A as a mother of three, and Grandmother B as a mother of two), they found themselves in an unknown neighbourhood and city, where they started forming friendships both with each other and with other women in their neighbourhood. Their daughters – Mothers A and B (fifty-one years old, married, full-time headmistress at a school) – also formed a friendship with each other and with other children in their neighbourhood (including their siblings). After they grew up and moved out of their homes, the two of them continued to meet whenever they visited their mothers. As a result, their children also met each other, with Child 2 and Friend B (female; eighteen years old, student) becoming friends. Due to the participation of Grandmother B, Mother B and Friend B, we could observe the vertical transmission pathway within an additional three consecutive generations. Figure 1 above shows the vertical and horizontal transmission pathways within this social network.

Apart from the above, we also recruited (i) a peer of the Father – Friend D (male; fifty years old, married full-time nurse supervisor) – who has been a close friend of his for over twenty years, (ii) a peer of Child 1 – Friend E (male; twenty-five years old, university student) – whom he met during their military service seven years ago, and (iii) a peer of Child 3 – Friend G (male; fifteen years old, student) – whom he met at an extra-curricular activity two years ago. Finally, we recruited (iv) an additional peer of Mother A – Mother C (female; fifty years old, married, nurse supervisor), whom she met at work almost thirty years ago, and (v) an additional peer of Child 2 – Friend C (female; eighteen years old, university student), whom he met when their mothers visited one another and with whom he became very close over the last three years.

We should note that all the participants are members of families in which the parents are married and live together. Also, for each participant who is a parent, he/she lives with his/her spouse and their children. Though the Grandmothers A and B are both widowed, their husbands also lived together with them and their children until they had all grown up and had become parents of their own.

2.2 Data collection

We used two different methods to collect data: observation and semi-structured interviews. The interviews constitute our primary method, as they contain information regarding the perceived behaviour of the participants' parents, of themselves, and of their (grand)children. To triangulate our data (Guion, Diehl, & McDonald, 2011; Triangulation, 2014) we also collected observational data, which allowed us to compare the perceived behaviours with the observed.

2.2.1 Observation

The observation and recording of the participants' behaviours took place prior to the interviews, so as to not bias these behaviours (e.g., questions regarding the amount of housework participants carry out are asked after the experimenter has observed how long they spend doing housework). It lasted for twenty four hours per participant, spread over four days (around six hours of observation per day). While observing each of the members of Family A[1], the first author completed an observation log (see Appendix E) by hand. This included all the

[1] Only Family A was observed during this study. Due to Covid-19 restrictions, the first author did not spend time (other than what was required for the interviews) in the other participants' homes, and she did not conduct observations with them. She only came in contact (no mask, for several hours) with one participant outside her family home: Grandmother A.

housework activities that the participants conducted, as well as specific notes regarding the way they conduct them (e.g., “Mother A sweeps by pulling the broom towards her”, “Child 2 sweeps by pushing the broom away”), the duration of the activity (in minutes) etc., to investigate more closely the transmission of behaviour within the family and make comparisons.

The observations took place in two different households: (i) the Grandmother A’s and (ii) that of the Mother, the Father and the three Children (Family A). During the observation process, the researcher remained silent and avoided engagement with the participants.

2.2.2 Semi-structured Interviews

After the completion of the observation process for each participant, semi-structured interviews were conducted with each of them individually. Our interviews consisted of a set of close-ended (e.g., “Do your parents spend time doing housework?”) and open-ended questions (e.g., “How does doing housework make you feel?”). Each interview lasted approximately twenty minutes (mean=18.4 minutes, SD=6.23 minutes). The talking speed of the participant and his/her elaboration on the topics affected the duration of the interview (max=28.38 minutes, min=6.67 minutes), but not the data collection, as every participant provided data on every subject.

The interviews opened with a set of probing questions to start the conversation and steer it towards the subject of housework, such as “How many hours a day would you say you spend at home? What do you typically do in those hours? Would you say that you do any housework? Why/why not?” (for the full set of topics covered in each interview, see Appendix F). The questions were initially developed based on previously conducted interviews which collected data on similar subjects to ours (Cunningham, 2001; Klein, Graesch, & Izquierdo, 2009; Mikula & Freudenthaler, 2002). Then, they were modified through a process of pilot testing with five Greek-Cypriots (ages 25 to 81), response analysing and refinement (Brown & Miller, 2002).

Participants were asked to express their perceptions around the housework they do themselves, the housework that their parents, their children, other families etc. do, based on their thoughts,

their behaviour, and the behaviours they observe or about which they discuss with others on a daily basis.

2.3 Analysis

The interviews were translated into English from the participant's native Cypriot Greek to English by the first author, who is also a native speaker of Cypriot Greek and transcribed in a .doc format by hand. We used thematic analysis to analyse our data. According to and as developed by Braun and Clark (Braun & Clarke, 2006, 2014), thematic analysis is a flexible and unbounded data analytic method, which provides a systematic framework for coding qualitative data (Meli, 2018). More specifically, we used a 'theoretical' thematic analysis (Braun & Clarke, 2006), as we intended to explore the transmission pathways during cultural transmission of information.

We followed the 6-phase process of thematic analysis previously described (Braun & Clarke, 2006; Javadi & Zarea, 2016; Vaismoradi, Turunen, & Bondas, 2013): (1) "Familiarising with data", (2) "Generating initial codes", (3) "Searching for themes", (4) "Reviewing themes", (5) "Defining and naming themes" and (6) "Producing the report" (Braun & Clarke, 2006; p. 87). To familiarise herself with the entire dataset (Step 1), the primary investigator printed the transcribed interviews in order to read them. Afterwards, she arranged them into the participants' answers to common or similar questions (see Appendix E for question examples), in order to make broad comparisons and gain an initial understanding of the data. This, later, allowed her to generate the codes (Step 2). Our analysis was aided by the Quirkos (www.quirkos.com) qualitative analysis software. After uploading the transcribed interviews, we assigned a code to each of our participants' responses and quotes, which appeared as a bubble. Each bubble/code was of semantic content, with the aim of representing the quotes of participants as explicitly as possible. To manage better the content of our data, we developed broader categories, to which we assigned the initial codes (see Table 1 in Results and Discussion). This was achieved by constructing a thematic map in Quirkos (i.e., we connected the initial bubbles/codes with the category that best described it). Thus, we begun searching for themes (Step 3) that would correspond to cultural evolutionary theory and represent our data. The themes were of latent content, as the analysis was theoretical and, therefore, aimed to interpret the participants' responses based on the theory rather than simply be descriptive. The primary investigator developed three themes in accordance with the theory, which she shared

with investigators MT and MC. MT and MC were also given unit examples from the transcribed interviews, and were asked to place them into the themes, as a way to review and validate the thematic analysis (Step 4). After the three investigators agreed upon the categorisation of the codes and their assignment to the specific themes, the themes were named (Step 5) and the primary investigator initiated production of the report (Step 6).

2.4 Ensuring Validity

To ensure descriptive validity, the transcribed interviews were accessible by all investigators. The construction of the themes and core ideas was processed by all investigators and compared, so as to confirm their agreement around the descriptive data. Second, to ensure interpretive validity, all findings were discussed with the participants, to ensure that their thoughts and attitudes were represented as they intended.

3 Results and Discussion

3.1 Observation

The results obtained from observing the participants of Family A (see Aims and Objectives: Figure 1) suggest that its members (from grandmother to grandchildren) carry out certain tasks by following almost the same steps as their parents, even if the nature of the steps is sometimes cognitively opaque to them. For example, when folding laundry, Grandmother A places all the clothes on the bed and then, she starts to fold them. She starts with larger pieces of clothing and then, she moves on to fold the smaller ones, with socks being the last ones that are folded. Her daughter (i.e., Mother A) and grandchildren (i.e., Children 1, 2 and 3) do the same.

When asked why, Grandmother A explained that *"you do the large ones first… the socks must be last, because that's how you can see all the pairs and not torture yourself…"*. She also explained that this was not something she was taught as, growing up in a poor family, she and her sisters only had two or three sets of clothing (of which, one was for Sunday and, therefore, barely used or washed). The much smaller number of clothing pieces, along with their being hand-washed in cold water with soap bars, made the entire laundry procedure different for her when she was a child. As an adult, she married a man of significantly higher socio-economic status. Four years later, she, her husband and their three children became refugees after the Turkish invasion of Cyprus in 1974 and they lived in tents with other refugees until the Cypriot government built houses for them. Then, the Grandmother started to use a washing machine

and she learned how to sew new clothes for the members of her family. These two novelties meant that she steadily adopted new techniques for carrying out the laundry tasks, including how to fold it; techniques otherwise impossible for her parents to transmit to her. This was a point when she innovated intentionally (Cavalli-Sforza, 1986; Guglielmino et al., 1995), to solve a certain problem. When her oldest child (Mother A) was six years old, Grandmother A passed on her innovations to her and then, to her son and other daughter.

When Mother A was asked why she folded the laundry following that procedure (starting with the large pieces and finishing with the socks), she replied *"I like doing it like this"*, and one of her sons (Child 1) replied that *"that's how I learned"*. So, after Grandmother A (generation 1) innovated, she transmitted the behaviour to her daughter (generation 2) who adopted it for herself and then, transmitted it onwards to her Children (generation 3). This is an example in which later generations imitate their parents' behaviour with high fidelity and then, transmit onward that behaviour to their children. Thus, they secure the conservation of the behaviour through vertical transmission (Cavalli-Sforza et al., 1982; Cavalli-Sforza, 1986; Garfield et al., 2016), regardless of whether they understand the causal relevance, the functionality, or the intent of said behaviour or not (Gergely & Csibra, 2006).

However, Father A (Mother A's peer) also follows the same procedure. He had never observed Grandmother A folding laundry and he does not remember himself folding clothes or observing someone else do it growing up (which suggests that he did not learn this from his mother, his father, or his siblings). When asked why he follows that same procedure, he explained that *"this is how we do it…in our house"*, and, when asked how he started folding laundry, he replied that he *"…started when we [my wife and I] moved in together after we got engaged and we had to do our laundry"* suggesting that he adopted the specific behaviour horizontally, perhaps by observing his wife (i.e. Mother A), as he does not recall receiving instructions from her.

Another interesting example of vertically transmitted behaviour was the setting of the table. On Sunday, when the family gathers for lunch, Grandmother A places the plates on the table (in front of each chair which will be used), she puts the forks on the left side of each plate, the knives on the right side and then, a napkin on top of each plate. After this, each person removes the napkin from a plate, they take that plate, they put the napkin in its place, and they go to the stove to be served by Grandmother A or to serve themselves. By this procedure, at least two causally irrelevant actions can be identified: first the napkins could have been placed first on

the table without them needing to be removed by everyone and, second, the plates could have remained stacked on the counter next to the stove, where they eventually ended up for everyone to fill them up or have them filled up.

These two causally irrelevant actions have also been observed at the house where Mother A, Father A and three Children live. Child 2 began setting the table by placing the plates on it and he asked his brother (Child 3) to help by bringing the napkins and placing them on top of the plates. Then, they placed the forks and knives together. When the family was gathered for dinner (prepared by Father A that night), everyone took a plate, they put the napkin in its place on the table, and they went to the stove to serve themselves.

When Grandmother A was asked why she performs these two actions, which appear not to be relevant to the cause of getting the table ready for lunch, she replied: *"I want the table to look nice for my family"*. When Children 2 and 3 (who had set the table at their house) were asked the same, Child 3 replied *"because my brother told me to bring the napkins"*, suggesting the horizontal transmission of said behaviour (the two brothers often set the table together), whereas Child 2 replied *"this is how we set the table"*, suggesting that this behaviour has become conventional to him at some point during his development, much like cutting the ends of the ham had become to Sylvia (Gergely & Csibra, 2006) before cooking ham. Perhaps, then, if someone asks Child 3 in the future why he performs the specific behaviour, he – much like Sylvia and his older brother – will provide an explanation similar to "this is how we do it", "this is how my brother does it" etc., as he will have grown up to view the behaviour as normative. Future studies could focus on determining the age at which behaviours such as the above become conventional.

Overimitation (i.e., faithfully repeating the actions of a model even when these are causally irrelevant) has been argued to serve differently functional and conventional actions (Legare et al., 2015; Clegg & Legare, 2016; Moraru et al., 2016). In the two examples above, Grandmother A's actions appear to have functional value to her (e.g., folding the socks last makes it easier to form the pairs and, setting the table like that serves aesthetic purposes). These actions seem to have been transmitted vertically either directly (from grandmother to mother, and from mother to children) and/or indirectly (from grandmother to the children). Both examples support that the vertical transmission enables the conservation of specific cultural traits for more than two generations (Cavalli-Sforza & Feldman, 1983; Guglielmino et al., 1995), and that, overimitation is one of the mechanisms that support the faithful transmission of said traits

for many more (Nielsen & Tomaselli, 2010; Nielsen et al., 2014). As Gergely and Csibra (2006) describe: “it seems to be a central characteristic of human culture that many of its products are cognitively opaque to the learner in a variety of ways”, yet specific traits can survive in “the family culture for all those years in this cognitively opaque form even though the conditions rationalizing the procedure as functional had long been absent.” (p. 7).

3.2 Interviews: Thematic Analysis

In general, substantial differences were identified when comparing the data collected from our interviews with participants from Family A and Family B, and participants from Family A and their peers, especially with regards to their behaviour and their perceived behaviour of other members of their families. These differences are discussed within three themes: (1) individual learning, (2) horizontal transmission pathway and (3) vertical transmission pathway. Each of the themes contains both housework-related behaviour (i.e., observable traits, such as cleaning, washing, tidying up etc.) and attitudes towards housework (e.g., perceptions about each person’s responsibilities, opinions about how the housework should be divided, feelings towards doing chores etc.). Table 1 below provides two unit examples (derived from the interviews with our participants) associated with each theme.

Table 1: The three themes in which the interviews were analysed, including two unit examples which fit into each one. Each unit was coded and categorised before being associated with the relevant theme.

Unit Example	Code	Category	Theme
“I wash them differently than the others in the house now. So, I guess I see what works and what doesn’t on my own.” (Child 1’s Peer)	Trial-and-error	Strategy for Individual learning	Individual Learning
“I saw them at the supermarket, and I thought they might work better for our clothes, and they do.” (Mother)	Environmental Availability of Resources	Reasons for Individual learning	Individual Learning
“She told me her recipe for pumpkin pies… and I showed her my rolled spinach pie and she liked it and I told her how I made it.” (Grandmother)	Friend-to-friend transmission	Outside the family horizontal transmission	Horizontal Transmission Pathway
“I watched my sister making crepes… I asked her to show me, and she taught me the recipe… and how to cook them.” (Child 3)	Sibling-to-sibling transmission	Within the family horizontal transmission	Horizontal Transmission Pathway
“Because the glasses are cleaner and because this was something my mom told me since I was a child: we firstly wash the glasses” (Mother)	Mother-to-daughter Transmission	Direct Vertical Transmission	Vertical Transmission Pathway

"She [my Grandmother] taught me how to fry eggs when I was small… I like her recipe for the minced meat, that's how I cook it" (Child 2)	Grandmother-to-grandson Transmission	Indirect Vertical Transmission	Vertical Transmission Pathway

3.2.1 Individual Learning

In summary, the instances in which participants believe they have achieved individual learning are few, and they include cases in which they learn from social media (such as Facebook) and from video-modelling (such as TV commercials and video guides).

For the purposes of this study, individual learning is referred to as the process by which participants have acquired/learned behaviour without having been taught or having observed a model in their family or peer environment perform it, by using environmental cues (Perreault et al., 2012), and trial-and-error (Mesoudi, 2011; Paul et al., 2016) strategies.

Some participants mentioned that they had learned how to execute some housework tasks individually. Interestingly, some similarities were detected among participants and their peers, mainly with regards to how or why they individually learn. It is possible that some of the similarities are due to their age and, therefore, the chronological periods in which they grew up, as the presence of different technological means has affected their individual learning strategies. For example, when asked how he started to use the cleaning products he had mentioned, Father A replied: *"Some I learned from TV commercials"*. Similarly, Friend D (a close friend of Father A's for almost thirty years), replied to the same question: *"it's what the TV shows"*. In contrast, no participant in the third biological generation mentions TV commercials. They do, however, mention the Internet as their source for, e.g., recipes: *"then, growing up, I learned to look up recipes on the Internet"* (Child 2), *"Facebook usually has nice cooking ideas and I try them out"* (Friend C), *"There are many [recipes] I got online, like for cupcakes"* (Friend B).

Different reasons led to them turning to individual learning and not social learning. For instance, Grandmother A explained that she cooks some meals differently from how her mother and sisters used to make them when she was young, because, after her marriage, she gained daily access to meat, an ingredient scarce while she was growing up:

"Other meals I make differently… very differently. [My mother and sisters] cooked different meals… they didn't have so much meat. They made other meals."

She, therefore, started trying different techniques to cook it, until she found the ones she liked the most, as she mentions.

Mother A mentioned that she started using different cleaning products after getting married and moving to her house due to their availability in her environment (e.g., supermarket) and their perceived functionality:

"…my mom continues to use powder detergent, whereas I use liquid… [I learned to use it] on my own. As with the fabric softener… I saw them at the supermarket, and I thought they might work better for our clothes and they do."

The three Children all mention that there were some products which they learned to use on their own, due to their availability within the house. For instance, when asked how he was introduced to Dettol and *"the mopping stuff"* he had earlier mentioned, Child 1 explained that *"Nobody taught me. I saw what we had at home and I used it"*. This post-hoc belief he constructed that nobody taught him is, almost certainly, contrasted with reality, as someone in his social environment must have taught him that the *"mopping stuff"* is, in fact, used for mopping and not for, e.g., cleaning the windows. Similarly, when Child 2 was asked how he learned to keep the spaces of his animals clean (the doghouse, the parrot cages and so on), he said: *"On my own… I usually use our dish detergent… because that's the best product we have for this"*. Finally, Child 3 posited *"I know dishes don't get clean with just water, that's why we have the detergent there"*.

All three Children, then, appear unaware of their social learning environment, as they assume that they learned many tasks individually, because it *"made sense to do [the chores] like that"* (Child 1) or because *"it's natural… you don't need instructions to do some things"* (Child 2), or, even because *"Most of the things I learned, I wanted to learn them, they didn't teach me to do it"* (Child 3). An example of this is washing the dishes. All three Children mention that they have learned how to wash dishes on their own. When asked if they remembered watching someone wash dishes – which would mean that they had a model from whom they had learned that specific behaviour – Children 1 and 2 replied that they do not recall such instances, whereas Child 3 said *"Maybe, because someone always washes… Maybe I was in the kitchen and I saw someone do it, but I didn't know to stop and learn… I decided on my own alone to learn"*. The participants' age, then, may affect their views on their individual learning, as the youngest Child does not dispute learning from a model, perhaps because the memory of learning was more recent (e.g., if all three Children were taught how to wash dishes at around the age of eight, Child 3 had learned this more recently – five years ago – whereas Children 1 and 2 learned this seventeen and nine years ago respectively). Therefore, the memory of learning was

more accessible to Child 3 than to his brothers. Another possible reason is that, as the youngest, he had more models to observe (i.e., Child 1 and 2 in addition to the older sister and the parents) and, therefore, it was easier for him to realise their presence and observable actions.

Washing the dishes is a task which other participants also perceive to have learned on their own, as it seems *"natural how to do"* (Friend B). Friend E explained that he learned the specific task using a trial-and-error strategy: *"I wash them differently than the others in the house now. So, I guess I see what works and what doesn't on my own."*. However, he remembers having been taught a different way: *"Washing the dishes I learned… either by observing or, maybe my mom explained to me how in the beginning."*. He also presents a post-hoc made-up belief that there were other tasks he learned individually, such as dusting, because *"…I think it was logical what to do. Nobody needed to explain it to me, I learned on my own."*. Yet, as per the dishwashing example above, it is unlikely that a learner sees the dust on the furniture, realises that it should be removed and automatically "invents" dusting techniques without guidance. Although Friend E does not realise this, he must have either received teaching instructions on how to dust or, at least, he must have observed a model dust.

In general, then, participants do sometimes learn on their own using different strategies, because those in their social environment lack certain knowledge (as in Grandmother A's case). Nevertheless, when knowledge is present – and, therefore, displayed in the participants' presence or, even, provided to them in the form of instructions – they appear not to realise that they acquired it from others around them (such as parents, siblings and so on), when the task at hand seems too easy to do, or too simple, to the point where they will even dispute the existence of a social learning environment.

Our data implies that this pattern could be more likely to appear in older participants and, therefore, there could be a developmental increase in the tendency to attribute learning to one's own self and not his/her social environment. Future studies could examine this hypothesis, as well as focus on identifying the age at which children seem to "forget" having learned how to execute simple tasks (such as washing the dishes), and whether this depends on the recency of teaching events, on the availability of observable models, or on other factors. Longitudinal studies could also investigate participants before they become parents and examine whether those who dispute having been taught such tasks actively teach their children how to do them, in addition to whether their children (at adolescence or young adulthood) recall their parents' teaching or not.

3.2.2 Horizontal Transmission

Apart from individual learning, our data provide evidence of cultural transmission, as there are tasks which participants recall learning socially from their peers (such as friends, siblings, and neighbours). This horizontal pathway of transmission has been argued to lead to cultural change (Guglielmino et al., 1995; MacDonald, 1998), as the transmitters' innovations on cultural products are readily accepted by learners of the same cultural generation and spread rapidly to other learners (Lycett & Gowlett, 2008).

3.2.2.1 Horizontal Congruence

Indeed, some horizontally transmitted behaviours have been adopted by our participants for themselves and transmitted onwards to other of their peers, as well. For instance, Mother A recalls learning to use cleaning products she had not used before from her peers (*"Some [I learned] from my friends"*), though she clarifies that, horizontally, she learned *"not how to clean, but some products I use, disinfectants"*. Presumably, the two behaviours – how to clean and cleaning products – follow different transmission pathways, with the latter following a horizontal one (i.e., being passed on from peer to peer and not from parent to child).

Grandmother A provides another example of horizontal transmission. She explained that, while growing up, her family's house did not have built floors. The cylindrical wall (which formed the only room of their house) surrounded part of the natural ground (an area of dirt), which they daily sprayed with water to keep it from forming dust. After her marriage she moved into a house with floors, which she *"needed to learn"* how to clean from her peers:

"You learn from other people, from your neighbours… When you go somewhere and see that, here there are floors, you understand you need to do things differently".

Then, when Grandmother B made her acquaintance, Grandmother A transmitted onward to her the traits of her peers. For example, she *"…showed her where to find and buy her [cleaning product x], because it was the best for the floors back then"*. They also started exchanging recipes *"for pumpkin pies… and I showed her my rolled spinach pie and she liked it and I told her how I made it"*. Soon, the five neighbouring women (all recent refugees) started exchanging recipes, as they sometimes met to have coffee and discuss local news: "if someone made really good [pies/desserts/food] we asked her for the recipe" (Grandmother B)[2].

[2] In accordance with the literature (Bianchi, Milkie, Sayer, & Robinson, 2000; Forste & Fox, 2012; Kroska, 2003), Grandmothers A, B and their peers appear to have been the ones responsible for the cooking within their households.

Interestingly, the two Grandmothers did not seem to share the recipes provided by their peers with their children: *"They [my children] liked my things better, so that's what I made for them and that's what they make now"* (Grandmother A) and *"…my daughter calls me to ask me how to make this and that, I tell her my way and my recipe because that's what I know by heart"* (Grandmother B). Their tendency to adopt their peers' behaviour for themselves and to transmit it onward to other peers – but, not to their children – can be attributed to the context-congruence bias previously found to affect cultural transmission (Chapter 3).

We can, therefore, hypothesise that behaviours transmitted from peer-to-peer possibly continued to follow that same (horizontal) pathway more often than they did a vertical one. By extension, one could assume that the behaviours of peers (e.g., Grandmother B innovating by combining the cooking strategies of her peer with her own) likely survived within that cultural generation – i.e., that of the Grandmothers' – and that they will perish when its members die (i.e., Mother B will never have learned Grandmother B's combinatory innovation) if they compete with vertically transmitted behaviours (e.g., Grandmother B will transmit her own strategy to Mother B, which is why Mother B will never learn the combinatory strategy). Testing such hypotheses would allow us to advance cultural evolutionary theory, as we could begin to understand how horizontal congruence affects the conservation and the omission of traits from the learners' social environments and explain phenomena such as language conservation and language death (Janse, 2003; Nelson, 2006).

3.2.2.2 Sibling-to-sibling Transmission

The three children also recall learning behaviours from their peers, most commonly from a sibling. It is generally argued that siblings engage in horizontal transmission of cultural traits (Greenfield, Maynard, & Childs, 2000) by imitating each other (Howe, Persram, & Bergeron, 2019), and by teaching each other (Howe, Rosciszewska, & Persram, 2018). In fact, siblings can be very effective transmitters, as the learners frequently acquire their transmitted behaviours (Rabain-Jamin, Maynard, & Greenfield, 2003). Children 1, 2 and 3 all mention learning behaviours from each other and from their older sister, by both imitation and teaching:

"…you learn from seeing others… when we were small, I remember my sister putting the toys in the basket. So, I started putting them in there, too, until our mom told us that the basket was for dirty clothes". (Child 1)

"My siblings [brother and sister] also showed me many recipes… My brother showed me how to peel the potatoes without cutting my fingers and other [cooking] hacks… My sister showed

me how to wash the pan… If you put in it liquid soap first and then, water, you don't get burnt" (Child 2).
"My brother helped me [with the dishwasher] … half of the things I know, I learned by seeing someone do them, like I watched my sister making crepes… I asked her to show me, and she taught me the recipe… and how to cook them [the crepes]" and "I asked my brother and he showed me [what to put in the mopping bucket]." (Child 3).

Other participants also recall learning from their siblings. For instance, Grandmother B – who, like Grandmother A, lost her father at a young age and her mother was left alone with her daughters – mentions that she learned many housework related tasks from her older sister (who had taken over the housework, because their mother worked for long hours):
"I helped my sister out sometimes… I also watched my sister clean and do the rest in the house". Arguably, this pathway could also be considered "oblique", as her older sister had taken a more caretaker-like role towards her. However, an older sibling, regardless of his/her responsibilities in relation to the younger sibling, can be perceived as a peer by the latter, albeit, more knowledgeable than herself, but not to the point where they could replace the existing parent or an expert (Reyes-Garcia et al. 2016). Therefore, as in previous studies (Kline et al., 2013; Gallois et al., 2018; Mudd et al., 2020), we treat behaviour learned from older and more responsible siblings as horizontally transmitted.

As expected based on previous studies (Abuhatoum, Howe, della Porta, Recchia, & Ross, 2016; Howe, della Porta, Recchia, & Ross, 2016), the older siblings in our sample assumed a teaching position toward their younger siblings, with the latter realising their siblings' teaching intent and learning the target information. The older siblings have previously been found to adopt a variety of teaching strategies (Maynard, 2004) – including some which are similar to those of their mothers (Pérez-Granados & Callanan, 1997) – to transmit to their younger siblings cultural information (such as cultural routines including food preparation; Abuhatoum et al., 2016).

The literature, however, suggests that younger siblings can also adopt a teaching position towards older ones (Howe et al., 2016; Perez-Granados & Callanan, 1997), as they experience developmental changes "regarding the breadth of their knowledge and their motivation to teach" (Howe et al., 2016; p.8). Parents also mention that their older children learn many of their social skills from their younger siblings (Perez-Granados & Callanan, 1997).

Perhaps, then, the nature of the transmitted skills affects the direction of information transmission between siblings (older to younger vs. younger to older), with our data suggesting that older siblings transmit housework and sustenance related skills and knowledge to the younger ones (see also Rabain-Jamin et al., 2003), much like parents do (Hewlett & Cavalli-Sforza, 1986; Lozada, Ladio, & Weigandt, 2006). Further research focusing on the direction of information transmission (older sibling to younger and vice versa) is needed for us to understand how children socialise within the household and, later on, as cultural transmitters and learners in society (Howe, della Porta, Recchia, Funamoto, & Ross, 2015; Rabain-Jamin et al., 2003).

In addition, as older siblings and parents transmit similar information to the younger children, one could wonder whether older siblings transmit the cultural variants that their parents would have also transmitted to their younger siblings, or whether they transmit competing variants. For example, if Child 1 acquired two different ways of peeling potatoes, one from his mother (e.g., pull the knife upwards, towards yourself) and one from his peer (e.g., push knife downwards, away from your body), would he teach Child 2 the vertically acquired variant (i.e., their mother's) or the horizontally acquired one (i.e., his peer's)? In our data, the second case is supported by Child 1's behaviour, who explained that he had learned the cooking hacks which he passed on to his brother (Child 2) during his 2-year military service "from the other soldiers in the kitchen". Post-hoc questions have confirmed that Child 1's parents use different ways to, e.g., peel potatoes, which means that Child 1, by choosing to transmit his peer's behaviour to his brother, abides to the horizontal context-congruence bias.

Nevertheless, the absence of data supporting the first case – i.e., that older siblings may transmit the parents' variants to younger ones, thus "interrupting" the horizontal transmission congruency – does not constitute an argument against it. Future studies could further investigate the cultural transmission of information between siblings, as it can have important implications for their roles as cultural transmitters and the subsequent cultural variants they choose to transmit onward to others. For instance, when older siblings become parents do they transmit to their children the variants of their parents, the variants that they had transmitted to their younger siblings, or different ones altogether?

3.2.2.3 Spouse-to-spouse Transmission

Apart from sibling-to-sibling and friend-to-friend horizontal transmission, both Father A and his peer, Friend D, mention having learned some behaviours from their wives. For instance,

when asked how he was introduced to some of the cleaning products he uses, Father A replied that *"Some [of those products], my wife tells me to use because they clean things better… like the counter disinfectant, or the Dettol spray and, of course, the chlorine"*. When asked the same question, Friend D mentions that *"[my wife] shops for those things… I use them because she brings them home … I buy them sometimes. She makes me a list and I buy them"*. In addition, Father A explains that he uses *"a vacuum cleaner, because [my wife] doesn't like dust… she says the broom makes things dusty"*, and Friend D that he puts *"the knives upside down in the dishwasher… [because my wife] says it's safer"*. However, despite the many housework related traits that the women in our sample display, we have no data suggesting that they acquire any of these from their husbands, though Mothers B and C mention transmitting such traits – including tidying up, usage of cleaning products, ways to heat up food and so on – to their husbands.

The horizontal transmission of housework related behaviour between spouses in our data appears, therefore, to be unidirectional from wife to husband. We argue that, as previously supported, the time that men and women in our sample spend doing housework is affected by their transition into marriage (Gupta, 1999; Perkins & Demeis, 1996). As the literature suggests, women who adopt traditional gender roles after marriage take up the responsibility to keep their houses clean and organised, to prepare the food and so on (Bianchi et al., 2000; Poortman & van der Lippe, 2009), whereas men's adoption of traditional gender roles is associated with little or no household labour on their part (Kroska, 2007). Women's adoption of traditional gender roles – and the subsequent responsibility this brings with it – provides them with control over issues regarding household labour (Allen & Hawkins, 1999; Bianchi et al., 2000). Our results support such findings, as Mothers B and C appear to be the decision makers of who does what and how in their homes.

When discussing why she has decided to do most of the housework, Mother C provides her husband's working and arriving tired at home as a reason for her doing significantly more housework than he does, though they are both supervising nurses (at different hospitals) and they work similar hours. This is consistent with previous research (Pittman, Solheim, & Blanchard, 1996), arguing that women are sensitive to their husbands' stress and tiredness, so they "pick up the slack for their husbands on days when they arrive home stressed from work" (p. 464), but that husbands do not tend to do the same for their wives.

Yet, our results contradict previous positions that women with higher educational levels tend to adopt more egalitarian views regarding the division of housework and gender roles (Esping-Andersen, 2009; Lynott & Mccandless, 2000; Read, 2003). Mothers B and C are both highly educated women with masters' degrees in their respective fields. Still, they have adopted traditional gender roles and they have willingly undertaken most of the housework, because they feel that *"it is my responsibility as the mother"* (Mother C), or that it was natural because *"I am the housewife, who else would do all these?"* (Mother B).

So, if education and workforce labour are not accountable for women's adoption of traditional gender roles, what is? One possible answer could be that the husbands of Mothers B and C are also to be held responsible; perhaps they lean towards traditional ideologies that men should not be involved in housework, or they never did any chores as children and they never learned how to do any. However, men appear less responsible for the unequal division of chores than women do in our sample. Mother B mentions that her husband *"used to do some things differently … he dusted with the feather dust, I didn't like that…. He wrapped the sandwiches with aluminium foil, and it was unhealthy. I wrap them in cling film… he didn't use chlorine [to clean the bathroom]"*. Mother C mentions that, when they were first married and moved in together, *"[my husband] cleaned the whole house whenever he was at home and I was at work"*. As both mothers experienced displeasure with their husbands involvement in specific tasks and, even, guilt (e.g., *"it doesn't feel right to let [my husband] do things"*, Mother B), they took up their husbands' share of housework in addition to their own at some point in their marriage.

In contrast, Mother A and Father A appear to have an equal division of the household labour, not only between the two of them, but with their children, as well. This is a surprising finding, as Father A's mother was solely responsible for the household labour, and he did not do any chores growing up. Mother A, on the other hand, was actively involved in the housework as a child (according to both her own and her mother's interviews) – as were her brother and sister – possibly, acquiring the vertically transmitted attitude that housework is not the mother's duty or responsibility. In contrast, Father A must have acquired the opposite vertically transmitted attitude, as his father was not involved in the housework, and neither were his brother and sister. After their marriage, however, Father A became actively involved in housework, and even he does traditionally female tasks, such as general cleaning and cooking (Cerrato & Cifre, 2018; Starrels, 1994). This could mean that Mother A was "free" of the societal pressure to adopt the traditional female roles, which Mother B and C have adopted. Most probably, though,

it means the societal pressure – which is mostly associated with oblique (Alvarez & Miles, 2008) and horizontal (Hiller & Baudin, 2016) transmission – is not strong enough to interfere with the vertical transmission of gender attitudes within a family, which led to Mother A following Grandmother A's example and dividing the housework amongst her children (and, even, her husband), and to Mothers B and C adopting traditional gender roles as, according to our data, their mothers had done before them.

Apart from implications about the relative "strengths" of vertical and horizontal (and, even, oblique) transmission pathways, our data generate hypotheses regarding the role of women within a household. We believe that the uneven household labour division in the homes of Mothers B and C despite their husbands' previous experiences and attitudes, and the equal division of housework between Mother A and her husband despite the latter's inexperience in doing chores, reflects the women's effectiveness as cultural transmitters. The husbands – the learners in this case – "corrected" their behaviour to match their wives' desired behaviour for them. So, men adopt their wives' horizontally transmitted traits and attitudes (independently of what these are), which replace the ones vertically transmitted to them by their parents. This contradicts previous research, supporting that the parents' attitudes towards housework predict men's behaviour (Cunningham, 2001; Fernández, Fogli, & Olivetti, 2004). On the other hand, husbands are proved ineffective horizontal transmitters, as, when their attitudes contrast the attitudes vertically transmitted to their wives' from their parents, the wives reject the horizontal variants and, even, correct these to match their own, vertically-acquired ones.

Our results have important implications for the pathways of cultural transmission and the role of spouses and, especially, wives as transmitters. Further research could compare the effects of vertical transmission (from parents) and of horizontal transmission (from spouses) of attitudes on men's expressed views on household labour division and their behaviour. Our study provides helpful insight, which could be used to generate hypotheses for, e.g., tackling inequalities within the household and, subsequently, within society.

In summary, horizontally transmitted behaviour – i.e., from peer to peer – is evident in our participants' behaviour. It appears that such behaviour is transmitted onwards horizontally, as well, but not vertically, as it persists only within the same cultural generation of participants, and it does not get passed on to their children. The sibling-to-sibling instances of horizontally transmitted behaviour can be used to further understand the flow of information within the family as, despite sometimes adopting teaching strategies similar to those of parents, siblings

transmit to their siblings information acquired from other peers (such as friends), thereby abiding to the context-congruence bias during transmission. Finally, spouse-to-spouse horizontal transmission of housework related traits appears unidirectional, from wife to husband, and it seems effective enough to replace previously vertically acquired traits in men, but not in women.

3.2.3 Vertical Transmission

Acquiring and reproducing the previous generations' cultural traits – for instance, the traditional gendered division of household labour – can be considered adaptive, as both men and women avoid the negative consequences of deviating from said traits (Thébaud, Kornrich, & Ruppanner, 2019). There have been many instances in which the attitudes of our participants towards housework and the behaviours exhibited within their households appear to have been vertically transmitted to them directly (from one or both parents), indirectly (from a grandparent), and, in a few cases, reversely (from one or more of their children).

3.2.3.1 Vertical Congruence

Our interviews provide specific examples in which our participants learned a dichotomous cultural trait (i.e., a trait with two possible transmissible variants, see (Bisin & Verdier, 2005; Ram et al., 2019; Liberman et al., 2020) with one horizontally transmitted variant (from peers) and one vertically transmitted variant (from parents and/or grandparents). In these examples, the vertically transmitted variant is preferred to be transmitted onwards by our participants to their (grand)children and, therefore, it is conserved, unlike its horizontally transmitted alternative. In general – and in accordance with the literature (Hewlett & Cavalli-Sforza, 1986; Guglielmino et al., 1995; Garfield et al., 2016; Constantino et al., 2021) – we find that there is higher conservation of vertically transmitted family traits than that of horizontally transmitted peer traits. This is attributable to the context-congruence bias that may be operating during transmission, which leads to vertically transmitted traits continuing to be transmitted vertically (Chapter 3).

For instance, even though she has been living a significantly different way of life than that of her parents over these last fifty years (after her marriage and after her relocation to a non-invaded part of the island) and she has access to ingredients and cookware that her peers also do, the Grandmother still cooks some foods the way her mother used to:

“[I learned how to cook] by cooking with my mom… with my mom I learned how to prepare food… I listened to her, I saw her cook and then, on my own I cooked. I cook the beans in the same way”.
“We didn’t have tomatoes all year long, we had them for only two months. It’s not like now that you can just go to the market and buy anything you want all year long. My mom used to make a tomato sauce and we kept it for the whole year, and we cooked our foods with that sauce… I learned how to make [the sauce] from her, I still make the sauce and I cook many foods with it”.

As in previous studies (Lozada et al., 2006; Kenner et al., 2007; Calpito, 2020; Beck et al., 2021), our data shows that cooking traits can persist over several consecutive generations. Indeed, some – such as the usage of the sauce the Grandmother learned how to make and use from her mother – appear to have been transmitted and have persisted for four generations (great-grandmother to great-grandchildren):
“My mom makes us the tomato sauce. I don’t know how to make it, but we always have four or five jars of it in the fridge because we cook a lot with it… foods like roast, or the minced meat, I like adding the sauce to them… my mom added it to them … I make [foods] like that, too”. (Mother)
“We always keep that sauce. We make many foods with it, but only my grandmother knows how to make it… I put it in many foods, anything with tomatoes… the minced meat, or the meat in the oven and the potatoes” (Child 1).
“We always keep [grandmother’s] sauce in the fridge. My mom puts it in many foods… my mom taught me how to use it and where, because it doesn’t go everywhere”. (Child 2).

This cooking tradition was directly vertically transmitted over four generations from great-grandmother to grandmother to mother to children, even after fresh tomatoes and tomato-based sauces had become available in the market all year long. When Mother A was asked whether others in her social environment also use similar ingredients (such as her mother’s sauce) she replied: *“Many of my friends use tomato juice or paste… they buy these from the supermarket… we don’t really like the ready-made stuff… if I ran out of [my mom’s sauce], I would only replace it with fresh tomatoes*”. This is another example of the path-congruence bias: Mother A not only retains, but also passes on her mother's tradition to her children, while she ignores the “competing” horizontally learned variant (her peers’ preferred tomato juice/paste).

3.2.3.2 Observational learning

Other examples of vertically transmitted traits from Grandmother A to her daughter include general cleaning, gardening, tidying up etc. Some of these, Mother A realises she had learned by observing Grandmother A: *"some, I observed my mom, like moping, washing the dishes, sweeping… gardening… making the beds"*. She does not recall Grandmother A actively encouraging her to observe her performing such tasks, so she, presumably, has learned some behaviours through unguided observation (Csibra & Gergely, 2009). Observational learning, in general, can be effective (Blandin et al., 1999; Shea et al., 2000; Heyes, 2001) – especially when the observer and the model displaying the observed behaviour share a mutually trusting, strong social bond (Hansen, 1999; Szulanski et al., 2004), as our participants do with their parents/children – and it plays an important role in behavioural vertical transmission (Gaskins & Paradise, 2010).

It has been suggested that observational learning can be a powerful enough mode of learning, as to lead to conformity to certain behaviours (Cialdini & Goldstein, 2004; Huh et al., 2014). However, our data support that, for conformity to take place, the teacher/model needs to provide specific instructions to the learner. We have examples in which participants describe either doing a certain task *"incorrectly"* and being explicitly corrected by a parent (e.g., *"I don't remember how I started, but I was definitely doing it wrongly and little by little, after instructions from my parents I learned"*, Child 1; *"At the beginning [my mother] showed me by doing [the sweeping] and then she gave the broom to me … sometimes she said I did it incorrectly and so I had start over"*, Child 3), or receiving teaching/instructions on how to do tasks, sometimes prior to executing them (e.g., *"[My dad] taught me the names of the tools and what they do, then he taught me how to work correctly with wood…my mom taught me to scrape the wood before painting it"*, Child 2; *"my dad taught me to wipe off [the plates] and how to start the dishwasher"*, Child 3; *"[my mom taught me to] wipe the chair that I will put the clean clothes with an antiseptic wipe"*, Friend C etc.).

Nevertheless, the nature of housework-related tasks may be what necessitates that they are taught to the learner (and not just modelled for her to observe). Housework consists of some traits which could be potentially harmful to the young learners if transmitted in "incorrect" forms, such as cooking (Lancy, 2012). This makes teaching the learners necessary, so as to avoid injuries. In addition, our participants seem to associate the cleanliness of a home with their own and their family's health (e.g., *"[cleaning products are needed] to have a clean house*

where my family can live with a satisfactory level of cleanliness and hygiene", Mother A; *"[I do these chores] for hygiene, ours and my animals"*, Child 2; *"if you don't do the chores, dust gets everywhere and it's not healthy to breathe in the dust"*, Child 3; *"[My mom] likes to keep the house clean. Mainly for health reasons…"*, Mother B etc.); an association which can also be transmitted vertically according to our data. So, teaching the child/learner how to clean "properly" – to the point where the child conforms to the desired way of cleaning – can be associated with keeping the family (including that learner) healthy and safe. In contrast, letting the learner observe the cleaning of, e.g., the bathroom, without her noticing the usage of disinfecting products, could be associated with undesirable results (such as the spreading of germs). By extension, as conformity to desired traits can be adaptive – and deviation from it can be maladaptive – parents do not solely rely on their children's observational capacities, but they seem to complement it with explicit teaching cues.

Though our data suggests that parents are willing to complement their children's observations, we do not know how the children receive their instructions and if, in fact, they conform to certain elements because of the effects of teaching or due to the repetition of witnessing the execution of a task (e.g., receiving instructions on how to clean after having observed the father clean and vice versa). Further research could investigate the effects of teaching versus observational learning on children's probability of adopting their parents behaviour and to conforming to specific elements of it, as this could help us understand whether different mechanisms – e.g., observation learning versus teaching – of vertical transmission lead to different degrees of behavioural congruence between generations.

3.2.3.3 Pedagogy

Apart from being observers, many of the parent participants in our study describe instances in which they perceive themselves as the model whom their child had observed to learn a behaviour. For instance, Mother C recalls her daughter sitting at the kitchen table when she was small and watching her as she ironed: *"she didn't ask anything. She just watched for a while… [she did it] many times"*. Another example was Mother B remembering that her daughter sometimes observed her and her mother (Grandmother B) when they cooked or baked, and she would even *"bring a chair to stand in front of me to see better… as I cooked"*. Such instances of informal teaching by the parents (Paradise & Rogoff, 2009) could be associated with adults' "tolerance of close observation" (Kline, 2013) when children are socially learning a trait.

However, parents' willingness to "model" – or informally teach – a behaviour does not automatically mean that children will learn it. The learner needs to pay attention to the model and the displayed behaviour (Bandura, 1977, 1986; Goubert et al., 2011; Morse et al., 2019). Lewis (2008) refers to a "pedagogic process" (p. 297) prompted by the learner's curiosity. Some of our participants have realised their children's eagerness to learn. According to Mother B, her daughter *"mostly observed and wanted to try [many housework tasks]"*, while Mother C mentions that her daughter *"watched as I did the laundry and such… [she] liked the way I folded and wanted me to show her [how to do it]"*. Mother A also remembers that Child 2 *"would bring his little chair into the garden whenever I planted… [he was] around 2 or 3 years old… he looked as I planted flowers… it was interesting to him"*, though she mentions that he observed her actions, contrary to the daughters who copied their mothers' (B and C) actions.

Moreover, some (grand)parents in our sample have mentioned that they encouraged their (grand)children's observation of their actions for teaching purposes. For instance, Grandmother B mentions that *"[my granddaughter] needed to learn [how to cook] … I would say 'time to cook' and she would come to see… when she was young, before I let her help"*. Mother C describes how she *"let [my daughter] see [as I folded] the laundry… I would get face-to-face with her…so she could see what I did"*. Similarly, Mother A describes that *"… [my husband and I] showed [our children] where to put [their toys] … we grabbed a toy and put it in the basket [as they] watched us… you say things like 'look what I am doing' [to get children to pay attention]"*. Previous studies have also documented adults' sympathetic stance towards children's imitation of their actions, as well as the encouragement children receive to remain at a safe distance from the adults while they observe them execute a chore-related task and learn (see Lancy, 2012).

Based on our data, we could hypothesise that this stance becomes less common as the child grows older, as the parents in our sample all seem to mention instances when their children were young, small, etc. However, according to our participants' discussions, vertical transmission still occurs at later stages in life. When the children become older, they become more involved with the housework, even in the households of Mothers B and C, who mention that they ask for help from their daughters (but not from their sons) to cook or to set the table and so on. This means that, when they are young, children are encouraged to observe and try some chores, whereas parental encouragement becomes an expectation as they grow older. Or, perhaps at some point in their development, children adopt more active roles as members of the household, and they undertake more responsibility. Therefore, their parents become more

comfortable or accustomed to asking for their help with more tasks. If the latter is the case, it would imply that vertical transmission from parent to child is dependent upon the child's willingness to adopt new cultural traits and the parent-transmitter is sensitive to that, whereas, if the first is true, it would imply that the parent-transmitter determines the learning experience of the child-learner. Future research is needed to examine these hypotheses and answer questions such as, is vertical transmission occurrence dependent upon the learner's willingness to learn, or upon the transmitter's judgement that it is time to transmit? On the other hand, is it that the two simultaneously affect transmission?

Perhaps, to explain (i) the (grand)parents' willingness to allow their (grand)children to observe them and their active seeking of their attention – often at the cost of efficiency of the task they are executing (Lancy & Grove, 2010; Kline, 2013) – and (ii) children's receptiveness to teaching and eagerness to learn, we could turn to natural pedagogy (Csibra & Gergely, 2009, 2011).

According to natural pedagogy, humans are predisposed to learn. Since infancy, humans respond to adults' ostensive communication signals – such as gaze direction and eye contact (Senju & Csibra, 2008; Wu et al., 2014) – which signal the adults intention to teach. Thus, learners acquire the observed behaviour, including the components whose causality is opaque to them (Csibra & Gergely, 2009, 2011; Hewlett & Roulette, 2016; Bettle & Rosati, 2021).

As it requires active participation by the teacher during the transmission of behaviour to the learner (Csibra & Gergely, 2006), natural pedagogy is costly to the teacher (who is to engage in an activity beneficial for the learner and not herself). Therefore, it is expected to "be selected primarily to support vertical (parent to offspring) transmission of knowledge" (Csibra an& d Gergely, 2006), a view supported by the data provided by our parent participants.

Natural pedagogy also requires that the learner infer the teacher's intention to teach and be receptive of the intended teaching. Csibra and Gergely (2006, 2009, 2011) describe a communication system, which facilitates pedagogy, according to which the teacher produces ostensive signals to indicate her teaching intent and specify her student as the addressee of this intent (see also Parise & Csibra, 2013). Indeed, our parent participants mention producing ostensive signals (e.g., *"you say things like 'look what I am doing'", "I would get face-to-face with her"* etc.) when they describe how their children learned some of their behaviours.

3.2.3.4 Cultural learning

Yet, our data suggest that ostensive signals in the form of eye contact or infant language were not the only ones used to transmit target behaviours. We have documented instances in which participants remember learning (or teaching) through instructions. So, to consider another dimension of the acquisition of traits and behaviours, we turn to cultural learning (i.e., the acquisition of cultural traits and conventions by children from their social environment), as proposed by Tomasello and colleagues (Tomasello et al., 1993b, a; Tomasello, 2004, 2016). In their papers, they have distinguished three types of learning. Of particular interest to this point is their proposed instructed learning, where the teacher intends to teach, and the learner intends to learn specifically what the teacher is trying to teach.

One example of instructed learning in our data is Mother A remembering that Grandmother A had actively taught her and her siblings how to do some tasks. She mentions, for example, that *"the dishes she always told us how to do"*. Indeed, Mother A seems to start always with washing the glasses, first, before she moves on to the plates and cutlery, *"because the glasses are cleaner and because this was something my mom told me since I was a child: 'we firstly wash the glasses'"*. Grandmother A does the same ("first you wash your glasses"), though she provides a different reason for doing so, thereby exhibiting that Mother A's constructed post-hoc reason did not correspond to reality: "…you get [the glasses] out of the sink first, so that they don't break". Mother A also recalls her mother instructing her how to iron and how to fold clothes. Moreover, when asked what cleaning products she uses, Mother A replied that she uses chlorine which *"was something that my mom always used"*, "*the Jif cream that my mom always used for the pots", "the liquid cleaner that we use for the stove", "the Brillos"* and, generally, that *"most of it was from my mom… [she taught me] how to use most of them"*.

3.2.3.5 Gender Segregated Transmission

Direct vertical transmission of traits is often observed from just one of the parents to the child (Al-Zu'bi, 2015; Davies & Fitchett, 2015), and in Mother A's case, we see direct vertical transmission of housework-related traits from just one parent: Grandmother A. Mother A mentions that her father did not spend time doing housework, and she does not remember learning something housework-related from him, though she remembers having a very close relationship with him and learning things of a different nature from him (mainly of academic nature). However, it should be noted that her father was significantly older than her mother

(contrary to the other couples in our sample), and both Mother A and Grandmother A expressed that he did some "easy" tasks (such as *"watering the plants"*; Mother A), whenever he could.

Other female participants also mentioned that their mothers were the ones who had directly transmitted to them housework-related traits, though their fathers are/were of similar age to their mothers. These traits appear to have been transmitted to them with high fidelity, which sometimes proves costly. For instance, Mother B mentions:
"[I use] the same cleaning products my mom does. The chlorine I try not to use too much, because I can't take its fumes, I almost passed down cleaning the showers once". She had earlier described a perceived attitude of her mother's (i.e., Grandmother B) towards chlorine (*"[she used] chlorine a lot, and in many forms… she thinks that chlorine can clean everything"*), in a doubtful and critical way. When asked, she explained that *"now there are other products, not so unhealthy that we should use"*. Yet, she still uses chlorine to clean (*"I do use it more than I should, too"*), even at the expense of her health, as she perceives it. As a mother, she has also transmitted some behaviours to her daughter, including the usage of chlorine for cleaning: *"My mom taught me how [to tidy up my room] … [the products] for the washing machine … you use chlorine [to clean the bathrooms]"* (Friend B). We could, possibly, attribute some instances of gender-segregated transmission (e.g., from just the mother to just the daughter) in our data to the closeness and intensity of the mother-daughter bond (Fischer, 1991; Peters, 1994; Rastogi, 2002), or to the matrilineal bias supported in previous studies (Euler & Weitzel, 1996; Chan & Elder, 2000; Holden et al., 2003; Perry & Daly, 2017).

However, our data suggest that direct vertical transmission of housework behaviour is not gender-oriented (e.g., from mother to daughter and/or from father to son), as previous studies had suggested (Alvarez & Miles, 2008; Cordero-Coma & Esping-Andersen, 2018; Giménez-Nadal et al., 2019), as the examples of vertical transmission of – in the case of our data – housework-related information are not, exclusively, observable within women (mother-daughter or grandmother-granddaughter). Some of our male participants recall learning from their mothers. Friend E, for instance, has learned how to execute some housework tasks from his mother, who has, according to him, not taught many of these to his twenty-year-old sister (who *"does not really help out"*). In fact, in one of the examples he provides, he displays overimitation: he often loads and unloads the dishwasher, and, apart from *"the tablets for the dishwasher",* he adds vinegar because *"my mom told me to add some vinegar … I don't know [why], maybe for the smells or maybe it cleans better, or maybe for the dishwasher?"*. Though

the function of adding vinegar in the dishwasher before he starts it *"every time"* is opaque to him, he continues to add it because his mother has instructed him to do so.

In addition, all three Children (male) provided examples of instructed learning, where their Mother taught them housework behaviours, despite also having a sister (not a participant). For example:

"…when [my sister and I] were small, I was maybe 4 or 5 and [my sister] was 6 or 7, [my mom] would take us in the yard with her and one of us held the shovel and the other the garbage bag and [my mom] held the broom… she taught us how to sweep outside and then, inside" (Child 1)

"[my mom and I] brought flowers home in the spring and [my mom] taught me how to plant them" … "[my mom] taught me how to clean the windows" … "There are cleaning products that mom showed me… [my mom] taught me that, for the surfaces and furniture, we use the disinfectant wet wipes, for mopping, also a disinfectant product, for the dishes the Fairy liquid soap, for the sink, we use chlorine to disinfect." (Child 2)

"My mom taught me where everything goes" ... "[my mom] taught me how to sweep and mop… she did it with me and she told me how". (Child 3)

Perhaps, then, the vertical transmission of housework-related traits is dependent upon the transmitter. Mothers B and C have chosen to transmit behaviours to their daughters, whereas Mother A has transmitted behaviours to all her children, independently of their gender. As with the spouse-to-spouse horizontal transmission, our data implies that the mother within the family is a powerful transmitter, in that she may be the one who primarily determines who does and learns what within the household, at least when it comes to housework.

3.2.3.6 Mother-to-child Transmission

Most participants recall learning housework-related behaviours from their mothers. For instance, Friend C remembers that she learned how to iron by observing her mother ironing and asking for instructions from her. Interestingly, when describing how she irons, she mentioned: "I hold the iron with my right hand, although I am left-handed". The interviewer has asked and confirmed that her mother (i.e., Mother C) is right-handed and that she held the iron with her right hand when Friend C was observing her. This is another example in which the child overimitates a behaviour exhibited by the parent: though more costly in time and effort, the left-handed child uses her right hand to perform the behaviour exactly as her right-handed mother, without questioning the functionality of using her right hand to do so. In

addition, the participant had mentioned that *"I wipe the chair that I will put the clean clothes in with an antiseptic wipe"*. When she was asked why she does this, the participant explained that *"my mom told me to… it kills bacteria"*. Apart from the above, she remembers her mother teaching her other laundry-related behaviours (e.g., *"my mom taught me how to fold socks"*), as well, but she does not mention learning from her father. Mother C's interview confirms that her daughter irons and, generally, that she helps her with the cooking and cleaning.

Mother C also mentions that she has learned some behaviours from her mother (not a participant in the current study):
"Some things I learned from my mom… The way I iron, some chores inside the house… for the food, a few things I learned from my mom… [my mom] irons almost the same way I do… I observed her once or twice [ironing], but it was done differently then, you needed different temperatures for different fabrics, now it's automatic…".
She also mentions that, whenever she tries to cook something and she is not certain of the recipe, she *"sometimes calls my mom and she tells me the procedure"*. Though she could easily search for said recipes online (as she owns a smart-phone, a laptop and a tablet and she is capable of comfortably using them), she prefers the more time-consuming call to her mother, because it will allow her to execute the *"small parts"* of the recipe like her mother does.

Friends B and C (the daughters of Mothers B and C respectively) both mention that housework *"should be distributed equally"* (Friend C) between the members of a household and that it is *"not right"* (Friend C) or even *"wrong"* (Friend B) that their mothers have a significantly bigger share than the rest of the family. When asked to compare the housework allocation in their family with that in others, they said *"Most of the work is done by the mom, the dad is outside, and the children do less"* (Friend B) and that *"I do more in the house than other people"* (Friend C). Their expressed opinions are similar, in that the mother is normally the one responsible for the largest portion of housework, but that the housework should be divided more equally. Nonetheless, neither of them appears to contribute enough to it, as to suggest that they have acquired contrasting attitudes for the housework division to those of their mothers. We, therefore, predict that, when they become wives and mothers themselves, Friends B and C will reproduce their mothers' behaviour: they will adopt more traditional roles, assume most of the housework load and, even, "correct" their spouses' tendency to take up a fair share of the work, thus conserving the vertically transmitted attitude that the mother is the one primarily responsible of the housework. As this would imply the association of vertical

transmission within the household with the perseverance of unequal gendered division (as per in our examples), future studies could test such hypotheses.

3.2.3.7 Grandparent-to-grandchild Transmission

According to our data, however, the mother is not the only source of vertically transmitted housework behaviours our participants have adopted for themselves. In fact, grandparent-grandchild transmission has been shown to affect behaviours of the grandchild, such as cooking traits (Jingxiong et al., 2007; Rhodes et al., 2016; Beck et al., 2021). Mother A mentions that some cooking traits she learned from her maternal grandmother, from whom she also acquired other housework traits (though she could not remember which, specifically):

"Cooking I learned from my mom, my grandmother… most of them [housework traits] was from my mom and my grandmother".

Grandmother A has also transmitted some housework behaviours to Children 1, 2 and 3. In fact, the Children only mentioned *"my grandmother"* or *"grandmother"*, without specifying to which of their two grandmothers they were referring. The interviewer clarified that it was the maternal (Grandmother A) by asking them to specify. Previous studies have indicated the strength of the bond between the maternal grandmother and her grandchildren (Eisenberg, 1988; Rossi & Rossi, 1990; Pollet et al., 2007) and, therefore, this was expected. Such indirectly vertically transmitted traits include, mostly, cooking:

"Cooking, again, [I learned] from both my parents and my grandmother… from [my Grandmother] directly and some went through my mom first" (Child 1).

"[My Grandmother] taught me how to fry eggs when I was small… how to bake the coffee… I like her recipe for minced meat, that's how I cook it" (Child 2).

Indirect vertical transmission of traits from a grandparent to a grandchild plays a crucial role in the conservation of said traits (Cavalli-Sforza et al., 1982). As evident from the interview with Child 3, some traits – mainly ones associated with traditions – may not have persisted had Grandmother A not transmitted them vertically:

"[Grandmother A] is the only one who knows how to make halloumi[3] in the family and that's why I am trying to learn, too… we make it every summer for the year… all of us together… we make the flaounes[4] together with her and she always makes us pastries and I try to learn how to make them, too, and she likes to teach me" (Child 3).

[3] Halloumi is a traditional Cypriot dairy product.

[4] Flaounes are traditional Cypriot pastries made during the Orthodox Easter.

Other participants also mention having learned behaviours from their maternal grandmothers. For instance, Friend D recalls that his grandmother taught him *"how to sew my buttons on my shirts… I lost a few buttons when I was a soldier [i.e., during his 2-year military service] and she would sew them back on for me but, in the end, [my grandmother] showed me how to do it myself"*. Friend B mentions that *"…my mom and my grandmother taught me [cooking]"* and *"[I learned how to do] the laundry from observing my mom and my grandmother do it…"* and, when asked whether she does the chores she learned from her grandmother (i.e., Grandmother B) in a similar way to her or a different way, she replied that *"I imagine that I do them similarly, because [my grandmother] is the one who taught me. That's how she does them, that's how I do them"*.

In summary, our data support that vertical cultural transmission can happen indirectly, from the maternal grandmother, specifically, to her grandchildren. In addition, some participants' perceptions support that their grandmother's vertically transmitted traits were passed to their mothers who, then, passed them to them, suggesting direct vertical transmission of traits. This has allowed the continuity of family and, in some cases, national traditions and their conservation for three generations, at least. Therefore, as per our results and previous studies argue, vertical transmission allows a higher degree of conservation and ensures the stability of cultural traits (see also Guglielmino et al., 1995).

Future studies could investigate whether the paternal grandmother can also transmit cultural traits of that or another nature to her grandchildren, whether this transmission can happen directly (from grandmother to father to children) and indirectly (from grandmother to grandchildren), as well as whether it affects or, even, disrupts, the vertical transmission of the maternal grandmother's cultural variants. Though currently the literature suggests a stronger bond between maternal grandparents and their daughter's family (see above), the paternal grandparents probably hold their own family traditions (even if their national traditions are similar or the same). Despite our data suggesting that the vertically transmitted attitudes to the husbands are replaced by their wives' horizontally transmitted ones, we do not have the numbers to generalise the specific findings, nor do we know whether, e.g., the husbands of Mothers B and C transmit to their children their wives' or their parents' variants. To begin to fully understand how information flows within family networks, to the point where we could predict the behaviour and attitudes of future generations, we need to focus on all the sources of cultural information and compare their effectiveness.

4 Conclusions

The general aim of this study is to improve our understanding of how cultural information flows within real-world social networks, including both what learners choose to acquire for themselves and what they choose to transmit onward to others, and to generate new hypotheses which will advance cultural evolutionary theory.

We interviewed three consecutive generations in family A (Grandmother A, Mother A, Children 1, 2 and 3 and the Children's Father) – from whom we also collected observational data – and family B (Grandmother B, Mother B and Friend B) to explore the vertical transmission pathway of housework traits. The two families complement each other's social network, as their members have developed friendships (Grandmother A with B, Mother A with B and Child 2 with Friend B). Apart from the two families, we also interviewed close friends (peers) of Father A and Children 1 and 3, and two additional peers, one for Mother A and one for Child 2.

We examined cases of horizontal (peer-to-peer) and vertical transmission (parent to child, grandparent to grandchild and child to parent) of cultural traits. Our results have important implications for the cultural transmission pathways different cultural traits follow and will continue to follow, and they yield questions regarding the relative effects of these pathways and the role of the transmitters on adoption and onward transmission. Our conclusions focus on three aspects of the cultural evolutionary theory, as presented below.

4.1 Vertical transmission leads to high conservation.

The vertical transmission pathway is, as previously discussed (Garfield et al., 2016; Hewlett et al., 2000), the key to the high conservation of traits across generations. In our data specifically, we have found instances in which familial and national traditions were conserved due to their vertical transmission to future generations. This is attributable to the learners' high-fidelity imitation of cultural information as transmitted by their parents and/or grandparents (Csibra & Gergely, 2011), to the point where they overimitate, as they adopt even the elements whose function, intentionality or causality is cognitively opaque to them (Clay & Tennie 2018; Hoehl et al., 2019; Lyons et al., 2007; McGuigan et al., 2011). Apart from adopting these traits for themselves, when they become parents, these learners transmit them onward to their children. Interestingly, their children also display the cognitively opaque elements, which suggests that they, too, overimitate their parents. Our study, therefore, provides further evidence that

overimitation is, in fact, a predictor of the high conservation and stability of culture, not only because it ensures adoption by the learner (Legare & Nielsen, 2015; Nielsen, 2018; Tomasello, 2016), but also onward transmission. Overimitation and its operation during onward transmission has not, to our knowledge, been discussed before, so this is an area worth exploring further.

4.2 Context-congruence bias

The previously proposed context-congruence bias – according to which vertically acquired variants will also follow a vertical pathway during onward transmission and horizontally acquired ones will be horizontally transmitted onward (Chapter 3) – is evident in many cases in our data. Vertical congruence is observed even during the transmission of a dichotomous cultural trait: transmitters who acquire two variants of the same trait (one horizontally and one vertically) choose to vertically transmit onward to learners – i.e., their (grand)children – the variant which they had previously acquired vertically (i.e., from their own parents or grandparents), even if they adopt both variants for themselves. Horizontal congruence is observed even in sibling-to-sibling transmission, as the transmitter (older sibling) will transmit onward to the learner (younger sibling) the cultural variants which he/she had previously acquired from a peer (even if these are in competition with vertically acquired alternatives), despite using teaching strategies similar to those of the parents.

By consequence, we can expect that cultural information will adhere significantly often to following the same pathway of transmission (vertical or horizontal), thereby highly conserving vertically transmitted variants for many generations, and rapidly diffusing horizontally transmitted ones for one generation. More studies are needed to test such hypotheses.

4.3 Horizontal transmission agents can interrupt vertical transmission.

Our results provide interesting insights about the relative "strengths" of vertical and horizontal transmission and how these relate to the context of transmission. Specifically, we have found that the vertical context-congruence bias could be weak when in competition with the wife-transmitter, who appears to interrupt the vertical transmission of traits. The spouse-to-spouse transmission in our data is always unidirectional from wife to husband. It appears that the wives' attitudes (at least, regarding the husbands' housework-related behaviour) manifest in their husbands' behaviour, even when the husbands had previously vertically acquired contrasting traits.

This finding could lead to two important implications for cultural transmission, which we need to examine further. First, it points to the relative effectiveness of the wife/mother transmitter in relation to the father/husband-transmitter within the household, at least when it comes to housework. Her transmitted behaviour and attitudes are adopted by her children and by her husband, who "corrects" or, even, replaces his previously vertically acquired behaviour. Further research is needed to examine whether the fathers transmit onward their wives' traits to their children – thereby contradicting the context-congruence bias – or they "revert" back to and transmit onward their own parents' vertically acquired traits – thus abiding to the context-congruence bias.

Second, the wife/mother transmitters in our sample appear to have adopted for themselves and transmitted onward their own mothers' traits. More data (empirical and ethnographical) could be collected to examine whether the maternal grandmothers' vertically transmitted variants tend to persist over the paternal grandmother's and/or grandfather's vertically transmitted variants to the husband/father transmitters. An interesting hypothesis is that any competing variants vertically transmitted by the paternal grandparents will be replaced or corrected, to the point where they will cease to exist. It could, then, be that the vertical transmission pathway can and does get interrupted by horizontal transmitters but only by horizontal transmitters with certain characteristics (such as those of the wife).

On the other hand, this yields new questions and hypotheses. For instance, if the husband-learner "abandons" his parents' vertically transmitted variants and, instead, acquires his wife's horizontally transmitted ones, does he transmit these onward to his children? Could it be that the horizontally acquired behaviour can follow a vertical pathway in some cases, thereby ensuring its conservation for, at least, one additional generation? And, if this is the case, how does this affect the up until now known dynamics of cultural evolution? If a horizontally acquired trait is commonly transmitted onward vertically, could it lead to changes as vast and as rapid as when transmitted onward horizontally? Alternatively, could it mean that it will be diffused more slowly but lead to higher stability within the population?

Further research is still needed for us to be able to answer such questions. Human culture is extraordinary, and it is forevermore evolving. Though we still do not completely understand it, this study has added new perspectives to the literature, much necessary to fill the gaps (e.g., how pedagogy, observational learning and cultural learning can be intertwined when it comes to teaching children housework), to test existing theoretical frameworks (such as overimitation

during cultural transmission and its role in cumulative culture) and to generate new hypotheses (such as the possibility of disruption of one transmissional pathway by the other).

Chapter 5
General Discussion

This doctoral thesis aimed primarily to advance cultural evolutionary theory by addressing gaps in the literature, specifically regarding the process of cultural transmission, and generating new hypotheses. To achieve this, it experimentally investigated factors that can affect the mechanisms of cultural learning and cumulative cultural evolution (CCE), it examined how the process of cultural transmission may be conditioned, and it explored how culture is transmitted and how it evolves in naturalistic settings.

This chapter summarises the main findings of the three studies (Chapter 2, 3 and 4[1]). It presents their implications for the theory, and it reflects on some limitations imposed by their methodologies. Finally, it discusses avenues for future research, as implied by the findings.

1 Summary of findings

The three studies included in this thesis advance our knowledge and understanding of the cultural transmission process. The Language vs Demonstration and the Onward Transmission in the lab studies focus on quantitatively investigating factors that can affect cultural transmission, and the Qualitative study qualitatively explores how cultural information flows in a real-world social network.

1.1 The Language vs Demonstration study implemented a linear transmission chain design to systematically compare the effects of language (in the form of verbal instructions) and visual demonstration (as per previous studies) as two distinct modes of cultural transmission on the likelihood that cultural information will be (over)imitated by child and adult participants, as well as on the likelihood that beneficial changes will accumulate over generations (CCE of efficiency). The transmitted behaviour with which all chains (both the adult and child ones) were initiated was a sequence of two causally irrelevant and two causally relevant actions.

[1] For the purposes of the General Discussion, the following names will be used for each of the study chapters:

- Chapter 2: “Language vs Demonstration study”
- Chapter 3: “Onward Transmission lab study”
- Chapter 4: “Qualitative study”

In the verbal instructions condition, there were significantly more innovations (i.e., participants produced actions they did not witness) than in the demonstration condition, as hypothesised. However, the developmental increase in overimitation previously found (Berl & Hewlett, 2015; McGuigan et al., 2011a, 2007; McGuigan & Whiten, 2009; Moraru et al., 2016) was not supported by our results. In fact, children were more likely to overimitate under verbal transmission than were adults, an unprecedented finding in the overimitation literature. This may be because in our experiment we had provided both children and adults with instructions focusing on task completion before they attempted the task, in contrast to previous overimitation studies with adults (McGuigan, 2012). The results also suggest a greater extent of CCE of efficiency along the adult chains, while the child chains in the verbal instructions condition displayed the least CCE of efficiency. So, in adults, cumulative increases in efficiency are facilitated by language, with causally irrelevant actions being omitted from their output in the verbal instructions condition earlier in the chains and to a higher degree than in the demonstration condition. On the other hand, language relates to children's capacity to preserve cultural information along generations with high degrees of fidelity, even if that information is causally irrelevant for the practical goal of extracting a reward to them (e.g., actions not necessary to complete a task).

1.2 The Onward Transmission lab study examines social learning from a multi-generational perspective, that is, how the transmission of a cultural trait from a transmitter to a learner is conditioned by the context in which the transmitters had acquired it themselves. In parallel, this chapter incorporates Cavalli-Sforza and Feldman's (1981) proposed cultural transmission pathways: the vertical (and oblique) and the horizontal pathways. The main aim of this study was to investigate how the context of acquisition of a cultural trait – i.e., acquired vertically from an expert versus horizontally from a peer – affects the onward transmission of that trait, i.e., what the learner transmits to other learners. As the facet of onward transmission has not been investigated before, we created a novel experimental design. We manipulated the context of acquisition, during which the learner/participant acquires one cultural variant from an expert and another from a peer, and the context of onward transmission, during which the participant transmits one of the acquired variants either to a perceived peer (making him/her a peer), or to a perceived novice (making him/her an expert).

Our results show that a model-based "expert" bias affected onward transmission, with participants transmitting the expert's variant to new learners more often than the peer's overall. However, the difference between transmission of the expert's and the peer's variants is only

significant in the expert-to-peer onward transmission context (more production of the expert's variant). In in the peer-to-peer transmission context there is, in fact, slightly more transmission of the peer's variant. This indicates that an associative learning or a context-congruence bias (between the contexts of acquisition and of onward transmission) modulates the overall model-based bias favouring the expert. The context-congruence bias is the first factor found to link acquisition and onward transmission by a learner.

1.3 The Qualitative study encompasses a naturalistic study that explores how cultural information flows between and within three biological generations. Interview and observational data collected from fourteen individuals with different social relationships (e.g., filial, friendship, etc.) were qualitatively analysed. The main objectives of this study were to determine what cultural variants learners acquire and what they transmit onward to others, and to identify processes that may underlie acquisition and onward transmission. In doing so, we also aimed to enhance our understanding of why and how some cultural variants outcompete others, thereby possibly explaining the role of the previously proposed transmission biases (e.g., model-based, and content-based biases).

The theoretical thematic analysis was based on Cavalli-Sforza and Feldman's (1981) proposed cultural transmission pathways and, as such, three themes were extracted from our data: individual learning, horizontal transmission, and vertical transmission. Our results help explain how certain learning and teaching mechanisms, such as pedagogy (e.g., a parent asking for their child to observe their behaviour) and overimitation (e.g., that child copies the parent's behaviour, including the elements that are functionally, causally or cognitively opaque to them), enable the conservation of cultural information for at least two consecutive biological generations, and up to the maximum four generations for whom our interviewees provided information (great-grandparent to great-grandchildren). In addition, we found that the context-congruence bias proposed in The Onward Transmission lab study is an important predictor used to explain the continuity of vertically transmitted traits, and the survival of horizontally transmitted ones only within the particular generation that exhibits them. Nonetheless, we also discovered that certain transmitters – in our study, the wife-transmitter – may weaken the impactful vertical congruence bias. By successfully horizontally transmitting to the husband-learner the cultural traits she had acquired vertically, the conservation of said traits is ensured, as both parents (wife and husband) exhibit and transmit them onward to their children. Thus, we have evidence of a case in which "maternal" cultural traits outcompete the "paternal" cultural traits. The above may be used to generate new hypotheses (including that the maternal

and paternal variants follow different transmission pathways) and predictions (such as that the maternal variants will outcompete the paternal ones in, e.g., matrilineal societies). It would be beneficial to test such hypotheses and predictions, which result from our qualitative study, empirically by, e.g., comparing how many of the cultural variants that individuals exhibit are also exhibited by their mothers versus their fathers, and by their maternal versus their paternal grandparents.

2 Discussion and Implications

As stated in the Introduction, this thesis investigates cultural transmission by adopting a dual-inheritance approach to cultural evolution. Cultural transmission is, therefore, viewed as the process during which the learner copies cultural information present in her social environment. It is treated as a biased process (Boyd & Richerson, 1988; Richerson & Boyd, 2005), one that is affected by the learners' tendency to be selective with respect to when, who, how and why they copy (Henrich & Broesch, 2011; Laland, 2004; Rendell et al., 2011). It is a complex process and one that has not been easy to either tease apart and study or understand in its entirety. Still, invaluable work consisting of, amongst others, mathematical modelling and comparative studies (e.g., Boyd & Richerson, 1995a; Boyd et al., 2011; Cavalli-Sforza & Feldman, 1981; Cavalli-Sforza & Feldman, 1983; Feldman & Cavalli-Sforza, 1976; Laland, 1996, 2001, 2017; Richerson & Boyd, 2005; Tennie et al., 2006; Tomasello, 1996; Tomasello, 2001, 2014) has brought us much closer to doing so.

After closely examining the social learning literature, the proposed cultural transmission pathways, and the already established underlying biases (see Introduction), this thesis identifies and addresses some of the many remaining unanswered questions (Heyes, 2018; Mesoudi et al., 2004; Perry et al., 2021). The three studies shed light on the previously under-examined role of language during acquisition (Language vs Demonstration study), on the unexamined roles of the contexts of acquisition and of onward transmission (Onward Transmission lab study), and on qualitatively exploring Cavalli-Sforza and Feldman's (1981) and Boyd and Richerson's (1985, 2005) mathematical models (Qualitative study). Below, the main implications of the findings are discussed.

2.1 Language shapes the dual engines of cultural evolution.

Our findings illustrate that linguistic transmission (in the form of verbal instructions) significantly affects learners' reliance on innovation and imitation and, therefore, it affects cultural evolution.

Innovation is what primarily drives cultural change (Caldwell, Cornish, & Kandler, 2016). It can arise from both asocial learning (i.e., individual inventions) and a combination of social and asocial learning (including the modification upon acquired traits and the combination of acquired traits to create new ones) (Carr, Kendal, & Flynn, 2015). The latter is essential to CCE (Hochberg, Marquet, Boyd, & Wagner, 2017; Lewis & Laland, 2012), as these transmitted innovations accumulate to the point that they yield new products, that are more complex (Mesoudi & Thornton, 2018; Tennie et al., 2009; Michael Tomasello, 2001) or adaptive (Henrich et al., 2008; Tamariz, 2019).

2.1.1 Innovation

To understand CCE and its products, it is also important to understand what factors influence innovation. Our findings indicate that the mode of transmission is one such factor: it affects the tendency of both the adult and the child learners to rely on innovation, as learners acquiring cultural traits through linguistic transmission (Language vs Demonstration study) appear significantly more likely to deviate enough from their cultural input, as to generate innovations. Language, then, enables and perhaps, even encourages innovation. In contrast, learners of both age groups appear less likely to innovate when they acquire a trait through demonstration, to the point where they will rely on social learning significantly more often.

2.1.2 Imitation

Apart from the above, imitation – a social learning mechanism (Caldwell & Whiten, 2002; Dean, Vale, & Whiten, 2018) and Legare and Nielsen's (2015) proposed co-engine of cultural evolution – also appears to be affected by language during transmission, yet in contrasting ways with innovation in different developmental trajectories. Our results suggest that adult learners copy the causally relevant (i.e., imitate) and the causally irrelevant elements (i.e., overimitate) in their input with higher fidelity when they acquire it through demonstration, than when they acquire it linguistically. On the contrary, child learners copy the relevant elements with similar degrees of fidelity in either transmission mode, but they copy the irrelevant elements in their input with higher fidelity when these are transmitted to them through language.

2.1.3 Innovation and Imitation

Taken together, our results support that, in adults, language is associated with an increase in innovation and a decrease in (over)imitation (i.e., the social learning mechanism in our study), a trade-off previously assumed in Boyd and Richerson's (1985) model. However, the increase in innovation during linguistic transmission in children was not accompanied by the same decrease in (over)imitation. In fact, both overimitation and innovation increased through linguistic transmission. A positive correlation between innovation and social learning has been suggested before (Reader & Laland, 2002), with a focus on explaining biological aspects (brain size) of our cognition, and the subsequent illumination of cultural ones as well, such as informing the 'cultural brain' (Muthukrishna, Doebeli, Chudek, & Henrich, 2018; Whiten & van de Waal, 2017) or 'cultural intelligence' (Reader, Hager, & Laland, 2011; van Schaik & Burkart, 2011; Whiten & van Schaik, 2007) hypothesis.

The different equilibria between innovation and (over)imitation during different developmental stages and in different transmission modes may speak to the uniquely cumulative properties of human culture. The capacity to produce innovations is a requirement for culture (Whiten & van Schaik, 2007), as is their diffusion within the population through social learning mechanisms. It remains to be seen whether (over)imitation constitutes a requirement for this diffusion and their accumulation of innovative variants within a population (Boyd & Richerson, 1995a; Legare & Harris, 2016; Legare & Nielsen, 2015; Lewis & Laland, 2012; Nielsen, 2018; Tomasello, 2009; Tomasello et al., 1993a; Wasielewski, 2014) or if other forms of social learning can also enable diffusion and accumulation (see Caldwell & Millen, 2008a, 2009 for the suggestion that emulation is such a form). Our results, however, support that (over)imitation and innovation are both useful cognitive capacities which child learners exhibit, as they were able to transmit the observed behaviour with high degrees of fidelity (including its causally irrelevant elements) and, in parallel, introduce innovations in their outputs. We could argue, then, that (over)imitation and innovation allow children to inherit the transmitted products of the previous generations and to continue to adapt these to their new, changing environments. Legare and Nielsen's (2015) proposal that imitation and innovation work in tandem, then, not only finds support in our study (Language vs Demonstration study), but it is also enriched, with our results further suggesting that language shapes these engines, enabling them even more than demonstration does (as, compared to demonstration, verbal transmission increases innovation, it reduces overimitation in adults, and it facilitates overimitation in children).

Nevertheless, as soon as learners reach adulthood, innovation and imitation frequencies may become negatively correlated. When adults acquire cultural traits through language, they are less inclined to copy their causally opaque/irrelevant elements, including those which were innovations of their transmitters (see Language vs Demonstration study: adult participants copied significantly less causally irrelevant actions transmitted to them through language than did children). As Whiten and Van Shaik (2007) argue, "if more specialized social learning mechanisms are available [such as those available to adults] … then cognitively richer, more rarely invented innovations may be more reliably acquired by maturing individuals and their fitness enhanced accordingly" (p.611). Language appears to provide adult learners with enough information to make them more selective copiers than children, rendering the diffusion of certain innovations (e.g., causally irrelevant ones) less likely in a population of adults.

Of course, transmission mode on its own cannot account for the cultural evolution of products, a complex process that has been suggested to be affected, among others, by the interaction of factors such as content-based and model-based cultural transmission biases (McGuigan, 2012). This linguistically enabled selectiveness observed in adults, for instance, could be enhancing the diffusion of innovations whose innovator is someone of high-status or a perceived successful individual (Henrich, 2001). Similarly, content-based biases (Boyd & Richerson, 2005) could be affecting transmission in different age groups, as adults who are aware of the goal or task they want to achieve would select variants – including novel variants – that most reliably fulfil the function needs (the ones with higher content value).

2.2 A newly found context-congruence bias affects cultural transmission.

Based on our findings, we propose the existence of a context-congruence bias, which links acquisition and onward transmission and could be possibly stemming from the association of cultural variants with the perceived roles of transmitters and learners during their interaction. This leads to intergenerational congruence.

Mesoudi (2013) argues that to understand how cultural variants spread in a population we need to account for the different pathways through which these can be transmitted and to uncover the biases imposed on the learners. Richerson and Boyd (2005)'s pioneering work proposes a set of learning biases during transmission that allow individuals to selectively acquire adaptive cultural traits. Many studies have confirmed the effects of their proposed model-based biases (Chudek et al., 2012; Reyes-Garcia et al., 2008; Wood et al., 2012, 2013), the content-based

biases (Mesoudi & Whiten, 2008a), and the frequency-based biases (also known as 'conformity bias' and 'anti-conformity bias') (Kandler & Laland, 2013; Kendal, Giraldeau, & Laland, 2009; Morganand & Laland, 2012; Whalen & Laland, 2015).

Our findings, however, imply the operation of biases on what the transmitters pass on to learners, as well – i.e., referred to as biases during onward transmission in this thesis – and, therefore, the additional need to uncover and to understand these. Consider, for instance, what would mean for the learners in a population if most transmitters (e.g., their parents) show preference towards transmitting variant A (e.g., shake hands to make introductions) over variant B (e.g., kiss interlocutor on the cheek to make introductions) onward to them. The learners would be significantly more likely to observe variant A than to observe B (if they would observe B at all). Then, it would be much more likely for variant A to survive in that population, and this would not have been attributable to the effects of acquisition biases imposed on the learners – as there would, essentially, be no alternative for them to acquire – but of onward transmission biases imposed on transmitters.

Therefore, to understand how culture evolves, it is essential that we understand the entire process of cultural transmission, i.e., both acquisition (i.e., what the learner acquires) and the factors affecting it, and onward transmission (i.e., what that learner transmits to others) and the factors affecting this. Thus, in The Onward Transmission lab study, we controlled for frequency-based and content-based biases, and we investigated how the role of a transmitter and the role of a learner (model-based biases) in their transmitter-learner relationship can affect the onward transmission of cultural variants. This study constitutes the first experimental instance investigating such effects on onward transmission. In addition, this study explicitly assumes that individuals may acquire (learn and also deploy) several variants. Contrary to ours, other studies implicitly assumed that – although individuals may learn several variants of a trait – they will only select one of these to deploy, as guided by transmission biases (Brody & Stoneman, 1981; Burdett et al., 2016; Chudek et al., 2012; Corriveau, Fusaro, & Harris, 2009; Haun, Rekers, & Tomasello, 2012; Herrmann et al., 2013; Jaswal & Neely, 2006; Wood et al., 2016, 2012).

Our findings allow us to go beyond simply confirming the operation of previously proposed learning biases – such as the operation of a model-based vertical bias – and, even, beyond their hypothesised interactions (McGuigan, 2012). Our most important finding was the uncovering of a context-congruence bias, which operates both during acquisition (what the learner

acquires) and onward transmission (what the learner transmits onward to others), and which appears strong enough to 'modulate' the effects of a model-based vertical bias. According to this, learners are likely to be associating the social relationship formed between themselves and their transmitters with the cultural information that they acquire from them. For example, if a learner acquires variant M from her mother, then she associates that variant with what a mother transmits to her child. Analogously, if a learner acquires variant F from a friend, she associates that variant with what a friend transmits to another friend. Afterwards, when that learner becomes a transmitter for other learners herself, she will be most likely to transmit the variants she associates with her role in her relationship with the new learners. So, as per our example, she will be significantly more likely to transmit M to her children instead of F. She will, also, be significantly more likely to transmit F to her friends, instead of M. Thus, her daughter will be much more likely to acquire M and – even if she also witnesses and acquires F at some point – she, as her mother before her, will transmit M onward to her children.

This is a very important finding, as it brings us one step closer to understanding how cultural information is transmitted along and how it evolves in more complex social networks. The context-congruence bias leads to congruence between generations, whether this means horizontal congruence (variant F, for example, will be exhibited by members belonging to the same generation) or vertical congruence (variant M will be exhibited by members belonging to successive generations[2]). So, in a network made up of multiple relationships (filial, sibling, peer etc.), we can predict what cultural information its members will transmit and to whom, based on the context in which they acquired it.

2.3 The context-congruence bias aids our understanding of cultural evolution.

Our findings imply that the context-congruence bias is one of the factors we can use to predict the longevity, variability, and stability of cultural traits. They also illustrate that the biases during onward transmission could significantly impact the evolution of a trait. The need to alter the theory to account for biases on onward transmission is, thus, discussed.

2.3.1 Longevity

The context-congruence bias may help us predict the longevity of cultural information. It is a

[2] As per previous cultural evolutionary studies, this thesis also conflates vertical and oblique transmission under the label "vertical" (e.g., (Nielsen et al., 2012; Pagel & Mace, 2004; Theisen-White, Kirby, & Oberlander, 2011).

consensus in the literature that vertical congruence guarantees the continuity and the preservation of cultural traits for a minimum of two generations (Cavalli-Sforza et al., 1982) and it often forms products that are transmitted along many more generations (Boyd & Richerson, 1995; Caldwell & Millen, 2008; Mesoudi & Whiten, 2008b; Tomasello, 2009). In contrast, horizontal congruence can only guarantee the continuity of cultural traits for one generation (Cavalli-Sforza & Feldman, 1981).

The context-congruence bias is one that can connect cultural acquisition with onward transmission, and it illustrates the how transmitter-learner relationships may affect the likelihood that a cultural variant will be evident for a learner to observe, acquire and transmit. In other terms, it is a bias that associates *who* transmits *what* and to *whom,* by connecting certain cultural traits with certain transmission pathways[3]. By considering its effects, we may be able to predict the longevity of cultural traits. For instance, we can assume that, when a cultural trait becomes associated with, e.g., what a parent transmits to the child (i.e., with the vertical transmission pathway), it will be likely to continue to be transmitted from parents to children and it may persist for many generations. In contrast, a trait associated with what a peer transmits to another peer (i.e., with the horizontal transmission pathway) will likely cease to exist after the generation exhibiting it dies out. We can also assume that – all else being equal (e.g., variant intrinsic properties, transmitter effectiveness and characteristics, frequency of variant display etc.) – traits would be more likely to continue to follow the same transmission pathway as soon as they are associated with one, than they would be to follow a different pathway[4].

[3] A context-congruence bias may refer to variables other than the transmitter-learner relationship found in our study, such as time of day, who is present, location etc. For example, individuals may associate having toast for breakfast and cereal for dinner (time of day), or they may have salad with every meal when they are in one country and steamed vegetables when they are in another (location). Due to the context-congruence bias, they would, then, be more likely to transmit onward having toast instead of cereal for breakfast, having salad instead of steamed vegetables with every meal in Greece etc. All these variables may impact cultural evolution, but the effect of this particular transmitter-learner relationship context-congruence bias has very significant and, possibly, long-term consequences.

[4] It should be noted that, even though the context-congruence bias appears to be a factor affecting cultural transmission, it is not one that overrides all others. For instance, traits such as religion (which has been argued to be transmitted vertically; see above) spread initially horizontally, and then, continued to be passed down vertically along generations. In fact, some traits are transmitted in an alteration of pathways (such as technological gadgets). The context-congruence bias is one that may affect the likelihood that traits will follow one pathway, but not one that defines their fate. Future research would benefit from considering the effects of this bias in conjunction with previously uncovered ones, and ones that have yet to be uncovered.

So, when a trait is associated with horizontal transmission it is more likely for it to continue to be passed on horizontally than vertically and, therefore, it would be more likely for it to disappear from than to persist in the cultural 'pool' of the population as soon as the members of the generation exhibiting it die. On the contrary, when a trait becomes associated with vertical transmission and continues to be passed on vertically due to that association (as per the context-congruence bias's effects), it would be more likely for it to persist in the population's cultural pool than to disappear from it, because it will likely be acquired and transmitted onward by future generations as these are added to the population. Applied to Cavalli-Sforza and Feldman's mathematical models, we could argue that uncovering the strength of the impacts of this and other context-congruence biases is essential for advancing the cultural evolutionary theory, as it could be used as a parameter to fit evolutionary models and help predict the longevity of cultural traits.

2.3.2 Variability and Stability

Apart from trait longevity, the context-congruence bias can also impact and, therefore, help us predict the *variability* and the *stability* of cultural traits, as it combines the theoretical implications of Boyd and Richerson's (1985, 2005) and Cavalli-Sforza and Feldman's work (1981), who have already built a strong foundation for doing so. Cavalli-Sforza and Feldman discuss how different transmission pathways lead to different degrees of conservation and diffusion rates. Vertical transmission is highly conservative, it is associated with slower diffusion rates, it preserves within-group variation, and it leads to stability within the population. Horizontal transmission is associated with faster diffusion rates, it decreases within-group variability (and it increases between-group variability), and it can result in rapid rates of cultural change (Acerbi & Parisi, 2006; Eerkens & Lipo, 2007; Garland et al., 2011). According to the context-congruence bias, as soon as a cultural trait is associated with one pathway or the other, it is likely to continue to follow that. Applied to Cavalli-Sforza and Feldman's mathematical models, this would imply that the context-congruence bias promotes the increase of cultural variation and stability within the population regarding vertically transmitted traits (such as religion and political values; see above) and the respective decrease of these regarding horizontally transmitted traits.

Boyd and Richerson's proposed biases should also be considered when discussing *variability* and *stability*, as they can strongly affect the rates of diffusion and of cultural change. For instance, frequency-based conformist biases are associated with 'antinovelty' in a population

(Eerkens & Lipo, 2007): a system of many-to-one transmission renders the cultural variants exhibited by most transmitters as the most likely to be adopted by new learners, and innovations generated by the latter or by a small number of transmitters as less likely to become diffused. Thus, "conformity reduces within-group cultural *variation*" (Boyd & Richerson, 2005; p. 17). Since conformity is frequently evident among individuals of similar ages (Gabbert, Memon, & Allan, 2003; Haun & Tomasello, 2011; Knoll, Magis-Weinberg, Speekenbrink, & Blakemore, 2015; Morgan, Laland, et al., 2015) (though see Corriveau & Harris, 2010; Ma & Ganea, 2010 for pre-school children who tend to conform to adults), we could argue that it is a bias associated with horizontal transmission (i.e., during which learners interact with transmitters of the same or a similar age to theirs). So, conformity biases can be intertwined with horizontal transmission and lead to decreased *variability* and fast cultural change, i.e., decreased *stability*; though see (Hewlett, 2021).

Similarly, Boyd and Richerson's model-based biases could be argued to be intertwined with vertical transmission, especially in the cases where child learners acquire their parents' cultural variants over those exhibited by other transmitters (Corriveau, Harris, et al., 2009; Zarbatany & Lamb, 1985). The relevant attribute of the parents that makes them most likely to be copied has been argued to be familiarity (Wood et al., 2013), as they are the most familiar models (Learmonth, Lamberth, & Rovee-Collier, 2005), particularly during infancy and early childhood (B. S. Hewlett et al., 2000; Reyes-Garcia et al., 2016). In contrast with conformity and horizontal transmission, the model-based copy-parent bias, combined with the vertical transmission pathway, allows the conservation of the traits of previous generations, thus generating *stability* within the population and increasing *variability* among its members, as young learners are more likely to acquire their parents' variants and not those of their peers, who are also most likely to acquire their parents' variants.

In summary, the literature has benefitted greatly from Boyd and Richerson's proposed acquisition biases and the confirmation of these by recent studies, and from Cavalli-Sforza and Feldman's proposed cultural transmission pathways. Together, the two frameworks can be used to help us infer when culture is stable, when there is variability and how stability and variability are impacted by different social relationships and learning preferences. However, there still exists the need to better connect these frameworks – as they appear to be inevitably intertwined – and to understand the complexities they introduce to the theory, such as the multiple confounding factors arising from possible interactions of acquisition biases.

McGuigan (2012) proposes that acquisition biases could constitute a confound for the other. When considering, for example, frequency-based and model-based biases such as the ones mentioned above, this would mean that, if the relevant feature of the parents which makes them more likely to be copied than other models during early childhood is familiarity, parents are the models to whom children have the most frequent access and, therefore, their variants are observed more frequently than the variants of other models, such as peers'. So, it could be that the child learners' tendency to copy their parents is the result of an interaction of model-based and frequency-based biases. Similarly, the tendency to copy the majority (a bias to conform) may also be confounded by attributes exhibited by the transmitters. For instance, if in a population the majority adopts a variant associated with success (e.g., children of minority parents adopting the official language, which makes them more employable; (Bisin & Verdier, 2005), this would be the result of an interaction between conformist and model-based biases.

The context-congruence bias proposed in this thesis is a factor that can help us achieve this understanding. First, it allows us to connect the two frameworks (i.e., transmission biases with transmission pathways), as it is concerned with how the *relationship* between transmitter and learner influences cultural evolution. As The Onward Transmission lab study showed, learners can be influenced by model-based biases – e.g., they can be more likely to copy an expert than a peer – but even then, they do not transmit onward the expert's variants unconditionally. In fact, they transmit onward the peer's variant when another peer is learning from them slightly more often than they transmit the expert's variant, i.e., in a horizontal transmission context, and significantly more often than when a novice is learning from them, i.e., in a vertical transmission context. The context-congruence bias can, then, account for the effects of the acquisition biases previously proposed (as the model-based biases evident in The Onward Transmission lab study), yet it is not as restricted as these are and, therefore, it can also account for the transmission pathways. Acquisition biases are more concerned with which cultural variants learners exhibit after having observed or been taught more than one. Nevertheless, if a learner observes both variants E (from an expert) and P (from a peer) and goes on to exhibit only E, this would not, necessarily, mean that she disregards or 'forgets' P. In fact, she may exhibit E during one developmental stage and then, replace it with P later (Reyes-Garcia et al., 2016). But, most importantly, The Qualitative study showed that there may come a point where that learner, for example, will interact with another and – either consciously or not – deem the replaced variant more suitable for production (which may become transmission in the presence of learners) based on their relationship and revert back to exhibiting that for an observer. If we

were to test which variant she had acquired during the two different stages, however, we would probably find conflicting results, attributable to different acquisition biases and accountable for different implications.

The transmitter-learner relationships are flexible and ever changing: the young learners in the population will not always merely be learners and, as our studies (Onward Transmission in the lab study and Qualitative study) suggest, after they become the transmitters for other learners, they will not always transmit onward the same cultural variants to them. For instance, they may transmit a cultural variant they had acquired vertically as young children, or they may transmit onward the cultural variant they acquired horizontally during, e.g., adolescence. Our participants in The Qualitative study provide examples in which parents transmit to their children variants that they had acquired vertically themselves, and that may not be as efficient as their competitor variants, which they often acquired later on in life from a peer. In contrast, in our sibling-to-sibling (horizontal) transmission paradigms, the older siblings (young adults) tend to transmit onward a peer's (i.e., horizontal) variant to their younger siblings (adolescents; 17- and 14-year-old), while the older adolescent transmits onward the vertically acquired variant to the younger adolescent.

So, whether learners acquire the most familiar individual's variant, or the variant most common in their social environment should not be the sole point of enquiry. Therefore, the effects of the previously proposed acquisition biases alone are not enough to explain how cultural products are formed. Instead of solely focusing on these, we need to alter the theory to account for the biases underlying onward transmission, as well.

2.4 A unifying framework is needed to study cultural evolution.

This thesis has implemented three different methodologies and it has used both quantitative and qualitative means to study cultural transmission and add to the cultural evolutionary theory. Each of these has yielded important insights, which are even more advantageous when these methods are used as complementary to one another. I, therefore, agree with other scholars who have previously suggested a unifying framework to study cultural evolution.

The three studies comprising this thesis have a common point of enquiry, on which they expand: which factors define selective transmission and how these can, ultimately, affect cultural evolution. Both laboratory modelling and naturalistic approaches are implemented to inform different theoretical perspectives and to compensate for each other's "shortcomings"

(Mesoudi & Whiten, 2008a). As stated in the General Introduction and previously in this chapter, cultural transmission in the current thesis is not only concerned with the context of acquisition of information by the learners, but, also with the context of its onward transmission to further learners. The studies included, therefore, contribute findings to either one of these two facets, or to both.

2.4.1 The advantages of the linear transmission chains method

The Language vs Demonstration study focused on acquisition and, more specifically, how language, an extremely underexamined mode during transmission, affects the selectiveness of learners. It consists of a laboratory experiment, that tests how the selective acquisition of cultural information by individuals of different ages is affected when it is transmitted via language versus via demonstration. The findings – which became evident through the implementation of a linear transmission chains design – suggest that language and the age of the learner can, in fact, influence the process of social learning. Children are more likely to acquire even the causally irrelevant elements of the information passed down to them by the transmitter when the latter transmits the behaviour through language, than through demonstration. To put it in terms of biased transmission, children appear biased towards acquiring linguistically transmitted traits more so than visually observed ones.

It has previously been shown that the effects of even weak biases during acquisition can be magnified during cultural transmission (Kirby, 2017; Kirby et al., 2007), with the end-products of the population converging upon these (Griffiths, Christian, & Kalish, 2008; Kalish, Griffiths, & Lewandowsky, 2007). Yet, despite their importance to cultural-evolutionary theory, it has been observed that Boyd and Richerson's (2005) content-based biases (see Chapter 1) have not received much attention from dual-inheritance theorists, who focus more on model-based or frequency-based biases (Mesoudi & Whiten, 2008a). The experimental design of The Language vs Demonstration study provides an indication that language may affect or, at the very least, be involved in the shaping of cultural variants, such that they gain attributes that make them more or less likely to be preferred for acquisition than their competitors. That is, the apparent bias of children to acquire the variants that are linguistically transmitted may be a feature of the content-based bias: children may prefer to acquire these variants *because* they are/can be linguistically transmitted. The effects of this bias become amplified and are more visible as we move on to later generations in the child chains, especially when we compare them to the adult chains and, even, to the child chains in the demonstration condition, as in

both cases significantly more elements of the transmitted information are lost by the second generations in the chains.

The design of our study allowed the proposed content-based (linguistic) biases imposed on our participants to 'surface' in the cultural product of each of the chains. Particularly, our design has allowed us to attribute the end products of the child chains in the linguistic instructions condition exactly to the children's bias to acquire with high fidelity the linguistically transmitted cultural information of previous generations. Linear transmission chains designs are indispensable in studying cultural evolution, as they seem "most suited to identifying what Richerson & Boyd (2005) have called 'content-based' or 'direct' biases" (Mesoudi & Whiten, 2008a; p. 3491).

2.4.2 The advantages of novel designs to test mathematical models

The Onward Transmission lab study experimentally tests the mathematical models of Boyd and Richerson (1985) and Cavalli-Sforza and Feldman (1981), while the Qualitative study examines how their theoretical implications may be applied in a naturalistic study. These two chapters complement each other's results: the Onward Transmission lab study employs quantitative methods to cultural transmission under controlled conditions in the lab, and The Qualitative study employs qualitative methods, with data collection comprising of naturalistic observations and semi-structured interviews with individuals forming a real social network (consisting of fourteen individuals who have formed relationships, such as parent-child, friendships and so on). In doing so, this thesis further investigates the flow of cultural information within social networks, by examining the pathways of different traits and the dominance of one pathway over another. Together, the two studies advance our understanding of how cultural information is transmitted and how it evolves.

The Onward Transmission lab study, specifically, incorporates the transmission pathways proposed by Cavalli-Sforza, Feldman, and colleagues (Cavalli-Sforza et al., 1982; Luigi L. Cavalli-Sforza, 1986; Cavalli-Sforza & Feldman, 1981) in the experimental design to investigate how cultural transmission may be conditioned by the context of acquisition and, for the first time, by the context of onward transmission. As different transmitters form different transmitter-learner relationships, the design also allowed the investigation of the effects of Richerson and Boyd's (2005) proposed model-based bias on transmission. In doing so, this chapter demonstrated that the model-based bias can affect both acquisition and onward transmission, but a context-congruence bias – which, according to our results, operates on

transmission – can be a stronger predictor of which variants are transmitted onward and to whom, and it can modulate the effects of the model-based bias.

Our experimental design was novel, yet it still conformed to the usual characteristics of cultural transmission experimental modelling: it consisted of clear, measurable variables, it accounted for their interactions, and it controlled for factor variables outside our scope of study (such as transmitter gender, primacy/recency effects and others; see Onward Transmission lab study). As per The Language vs Demonstration study, the rigidness of our model allowed us to extract clear indications about the effects of biases on learners. Unlike the linear transmission chains design of the Language vs Demonstration study, we were unable to observe the magnification of the acquisition and onward transmission biases along generations, as, strictly put, we only had three events of transmission: from expert and peer to participant, then from participant to further learner. Nevertheless, this design allowed us to infer that there exist onward transmission biases, as well, and that the contexts of acquisition and onward transmission are in close association.

2.4.1 The advantages of a naturalistic study

The Qualitative study closely examines cultural transmission in the real world, by looking at the relationships formed by individuals with their parents, children, friends, peers, spouses etc., and how information flows within and between these. Although no single relationship in the sample was perfectly horizontal or vertical (e.g., a father-son relationship may be vertical, in principle, but in the context of, e.g., the two of them playing a game the vertical and horizontal 'lines' may begin to blur together), we could still extract conclusions about the pathway of the information more qualitatively and still use Cavalli-Sforza and Feldman's (1981) 'vertical' and 'horizontal' terminology as complementary.

As this study applies their theory within a qualitative setting, it contributes to the methodology by demonstrating the dynamics of the participants' connections with one another, how they form transmitter-learner relationships, why they 'prefer' some form of interaction over another (e.g., transmit to child instead of learning from her, learn from parents instead of transmitting to them etc.), how cultural information evolves within each network etc. Furthermore, this study closely examines the under-explored facet of onward transmission (as does The Onward Transmission lab study) and it advances cultural evolutionary theory by providing new insights, such as how cultural information is transmitted in a social network and why it evolves in its specific forms, and, most importantly, it informs future research by encouraging new questions,

such as how important the role of the mother is as a transmitter in the small population of her family.

The qualitative study design of The Qualitative study did not allow for the degree of variable control and manipulation of the previous two studies. Nevertheless, it provided insights as to how the theoretical implications of mathematical and experimental models can have real-world applications. It also allowed for the generation of new research questions and, most importantly I would argue, it provided a deeper understanding of how culture is transmitted and how it can evolve in a small social network.

In summary, all three studies have implemented different methodologies. Although each methodology may have its 'shortcomings' (see Methodological Challenges below), they have all enabled us to advance the, still, relatively new field of cultural evolution (Brooks, Waring, Borgerhoff Mulder, & Richerson, 2018; Shennan, 2015) in different ways. The findings extracted in this thesis, then, imply that the combination of different research designs is, perhaps, the most productive and effective approach to studying cultural transmission (e.g., (Mesoudi, 2015; Mesoudi & Whiten, 2008a). Mesoudi et al. (Mesoudi et al., 2006) even argue that biological evolutionists have achieved considerable advances in their field because they have taken advantage of the different methodologies (as used in different disciplines) available to them. Taking a page from their book, I would highlight that a very promising way to move forward is to account for the limitations of our methods, and to employ others, even novel ones, to provide fresh perspectives. It is also important not to exclude either quantitative studies (which bring the control, rigidness, and clarity necessary to testing the theories) or qualitative ones (which generate new ideas and directions), but, rather, to treat them as complementary to each other (Mesoudi, 2007).

3 Methodological Challenges

The timing of my thesis proved fortunate, as my research followed that of great scholars (including that of my supervisors), which meant that I had considerable guidance and, even, inspiration with regards to forming research questions and hypotheses. The experimental design principles we have followed have also been inspired by other studies, to the point that The Language vs Demonstration study implements the previously used design of linear transmission chains (Flynn, 2008; Flynn & Whiten, 2008; Hopper et al., 2010; McGuigan & Cubillo, 2013; McGuigan & Graham, 2010; Nielsen et al., 2012), and The Qualitative study

follows the analysing steps of other qualitative studies of three-generational families almost exactly (see Qualitative study; Methods).

In addition, I had the opportunity to explore new areas (e.g., the onward transmission process) and take different perspectives to previously asked questions (e.g., the individual effects of language on transmission), as the field of cultural evolution is, still, relatively new (Brooks et al., 2018; Shennan, 2015). As expected, then, the methodology presented thus far in the literature could not be considered ideal in its entirety for exploring topics such as those of this thesis, which investigate quite novel questions (Onward Transmission in the lab study and Qualitative study) and examine the practical implications of new theoretical findings (Qualitative study). Instead, we needed to adjust existing materials and designs and invent new ones to test our hypotheses. In doing so, we met some challenges. In the sections that follow, I outline the most important challenges we had during the design and execution stages of each of the studies. I also discuss how these were met, or, where it had not been possible, how these were considered in the discussion of the results.

3.1 Methodological Challenges: Study 1

For the Language vs Demonstration study (Language vs Demonstration study) we implemented the linear transmission chains paradigm (see Chapter 1) and, even, the apparatus previously used in overimitation studies (Horner & Whiten, 2005; McGuigan & Graham, 2010; McGuigan & Whiten, 2009; McGuigan et al., 2007). However, as we introduced additional variables (novelty and transmission mode; see Language vs Demonstration study) to the design, we needed to adjust (i) the apparatus, (ii) the modality with which each participant observed their input, and (iii) the overall chain allocation (according to transmission mode, age, and seed's initial action set).

It was also necessary for us to include the new variables without increasing the overall difficulty of the task or the time necessary to achieve it, to the point that it would become disengaging. At the same time, we needed the task to be achievable by both adults and young children, without making it so easy as to become uninteresting to them.

Our solution to the above was to cover the parts of the apparatus used in previous studies (the bolts on top), to remove the participants' 'original' options of causally irrelevant actions, both of which appeared to be unfamiliar/novel to participants in our first pilot and, thus, not suitable to test novelty as a factor. We, then, 'invented' two *novel* causally irrelevant and two *familiar*

causally irrelevant actions. Half of the chains were initiated with one set of four actions, two of which were causally relevant (and one of these was designed to be novel to participants while the other was familiar), and two were causally irrelevant (and one of these was novel to participants while the other was familiar). The rest of the chains were initiated with the alternative set of four actions, each of which had the same intrinsic properties (e.g., causally relevant and novel) as its alternative. By doing so, we introduced and controlled the novelty variable.

However, many of the actions that we had previously coded as 'novel' were spontaneously performed by the control group. This was the first methodological challenge of our design. As we could not overcome it (due to our analysing the control condition after we had already collected the data from the chains), novelty was not considered during the analysis, results, and discussion sections in our study. In retrospect, we should have run the control condition first to record and examine the actions individuals perform, and not include those as novel.

Apart from the above, children appeared more likely to treat the experiment as a game than were adults. This was expected, as children have been found to be more imaginative, and more capable of entertaining supernatural beliefs and magical thinking than are adults (Dix, 2003; Subbotsky, 2004; Woolley, 1997). Even though some of our adults – particularly towards the final generations of the chains, when causally irrelevant actions had become more abstract and symbolic for participants (e.g., waving the rod like a magic wand) – may have treated the task as a game, children appeared genuinely more interested in and excited by it. As a result, the children's visual input was different than that of the adults, because it appeared from the first generations as a game, perhaps engaging new learners better and providing a different 'spin' on the task overall (e.g., an attitude of 'finish the game' instead of 'complete the task'). Thus, the perceived nature of the task may have been different proved to be different between our two age groups. This was not a variable we were able to control.

Still, differences of such nature are to be expected when testing participants of different age groups, especially ones with such a large gap as our participants. This is further discussed in The Language vs Demonstration study, as is our reason for choosing the specific age groups.

In The Language vs Demonstration study, we also discuss the impact of the age of the model/transmitter. The participants in the child chains always observed/listened to a child transmitter, whereas the participants in the adult chains always observed/listened to an adult transmitter. The transmitter's age has been previously found to affect adoption of behaviour,

with adults' causally irrelevant variants being more likely to be adopted (McGuigan, Makinson, & Whiten, 2011b; Wood et al., 2012). Even though we intended for this in the designing phase of the study, we recognise that it may pose limitations to the interpretation of our results. However, our results were indicative of children's tendency to copy causally irrelevant actions more readily than adults, despite their transmitter being a child. This means that, had we controlled the transmitter's age, there would be stronger implications of the children's 'better' overimitative tendencies compared to adults, as they would overimitate their adult transmitters more readily (if all transmitters were adults), or the adult participants would overimitate the child transmitters less frequently than in our experiment (if all transmitters were children).

In general, however, the most unexpected challenge proved to be the recruitment of the participants. Many parents felt uncomfortable allowing their children to participate in a study, and some of the children whose parents had consented to their participation did not want to participate themselves. Due to this, the children were recruited from a wider variety of places (summer schools, different playgrounds etc.) and during different hours of the day (mornings, afternoons, and nights). Although the adult participants were more likely to participate once asked, they were also recruited during different times and in different places, as not many of them would gather to one place during the summertime. So, not all participants were recruited and provided data under the same – or, even, similar – conditions. This may have introduced new variables that influenced the results (e.g., children recruited at summer school could be more inclined to copy their input with high fidelity than were children recruited at a playground).

We tried to control for this during their allocation to generations and chains. For instance, most chains would include participants recruited from different places and during different times, so that they would resemble the conditions in other chains, as well. Still, this was not feasible for all our chains, which is to be expected during an experiment with human participants outside a lab.

3.2 Methodological Challenges: Study 2

The data collection for the Onward Transmission lab study took place in a lab, albeit with fewer participants, so it was easier to control the testing conditions. As this study set out to examine onward transmission and how it may be conditioned by acquisition, it included many variables (such as the transmitter, the new learner, the transmitted behaviour, and its variants etc.). Most

of these had not been previously integrated in experiments. We expected that this would be the case, because ours would be the first experimental instance in which onward transmission would be studied.

Still, deciding the transmitted behaviour (see Onward Transmission lab study: Materials) proved quite challenging. We needed a behaviour which could be transmitted in a short amount of time and have two equally difficult, effective, and time-consuming variants (i.e., the Expert's and the Peer's), in order to control for the effects of content-based biases. Taking a page from previous cultural transmission studies in the lab (Flynn, 2008; Flynn & Whiten, 2008; Hopper et al., 2010; McGuigan & Cubillo, 2013; McGuigan & Graham, 2010; Nielsen et al., 2012), we decided that it would be best to study the transmission of a 'solve-the-task' behaviour, too. After contemplating different task ideas, we eventually agreed to use our gear rotation task (see Onward Transmission lab study). We discovered two different strategies to complete it, both of which appeared equal (e.g., in complexity, difficulty, effectiveness and duration).

Selecting a task came with some risks, such as the feasibility of completing it by different participants. We piloted the experiment, and we made sure that it was engaging for participants and that it was achievable using either strategy. Also, we were aware that using a novel design could invite scepticism as to the validity of the experiment. To avoid this, we discussed all the possible variables that should be controlled, including the order in which each strategy was transmitted to participants, the order in which the expert and peer presented their strategy, the time taken to transmit each strategy and, generally, the interaction time between expert and participant and peer and participant.

The design became complex, and everyone who was part of it (myself and the confederates) needed to be informed of the specifics (e.g., what each role in the experiment means to the design), act in the same (or, at least, very similar) way toward participants, and play their part convincingly, e.g., that of the "novice", the "peer", the "expert" etc.. To do that, the five students who collaborated as confederates and myself met for several hours and rehearsed: each one had their own lines, their own gestures, and their own degree of engagement with the participants. The above needed to be stable across conditions and participants.

Finally, we ran the pilot of our experiment, after which we (researchers and confederates) were able to identify other possible confounding variables, such as the pace and volume of speaking. The pilot's participants were also helpful in suggesting ways to eliminate such variables. one of their suggestions was to eliminate eye-contact completely, as they felt that eye-contact with

myself, i.e., the experimenter, affected their decision later. The above were further rehearsed before launching the experiment. As a result, the design and preparation for the experiment proved more time-consuming than originally planned. However, in the end, the extra time was necessary for us to conduct a valid study.

During the experiment, we recruited the minimum number of participants deemed necessary for each condition, due to my own and my confederates' time constraints. Yet, two of our participants (from two different conditions, fortunately) had suspected the role of the confederates in the experiment and, thus, were excluded from the analysis (see Onward Transmission lab study). The number of our participants, then, posed a risk for our study. Thankfully, though, our data proved to be sufficient to answer our research questions.

3.3 Methodological Challenges: Study 3

This qualitative study did not involve complex statistical analyses, nor coding. At a first glance, it might appear that this would be the easiest and most straightforward study of the thesis. Yet, this was the most challenging study.

After proposing the idea of exploring three generations and their peers, we decided that this should be a qualitative study, to explore transmission in depth and surface new ideas and questions. Still, I was not trained in conducting qualitative research, and most of the literature I had studied consisted of quantitative studies and reviews. So, in the beginning, I studied the design, analysis, discussion of results, and writing style of qualitative research. After a considerable amount of time, I was ready to methodologically 'construct' the Qualitative study. So, the first challenge – i.e., the study design – had been effectively overcome.

The second challenge came when I piloted the study. The data collection would be achieved by my semi-structuring interviews and gathering the participants responses, in addition to documenting some of the participants' behaviour. The pilot participants (different than the ones whose data was used for the study) explained, after their interviews, that the questions I had asked them did not invite rich responses, and that the conversation had gotten stale after a while. In addition, some of them felt that the questions were leading them towards providing particular responses (e.g., a question such as "from whom did you learn x" may have led to them naming a person in their life, even if x was a behaviour they invented/innovated). Therefore, we changed the questions and I actively listened to the interviewees and built-up on their responses. The second pilot confirmed that the new questions were better, they were not

leading towards particular responses, and the new pilot participants felt encouraged to provide more information, much more relevant to the scope of the study.

Finally, the challenge that has taught me the most during my PhD was the analysis of the interview data. I had decided prior to the collection phase that I would use 'theoretical' thematic analysis (Braun & Clarke, 2006), as the main aim was to explore the pathways of cultural transmission of information (Cavalli-Sforza et al., 1982; Cavalli-Sforza, 1986; Cavalli-Sforza & Feldman, 1981). In addition, I had chosen to follow the 6-phase process of thematic analysis previously described in the literature (see Qualitative study; Analysis), and to use the Quirkos (www.quirkos.com) qualitative analysis software, which would help me organise the data.

Nevertheless, after transcribing the interviews, I realised that the data was much richer in both volume and information than I had originally expected. Due to my prior experience in quantitative analysis, I found 'escaping' the quantitative approach to data and focusing on the quality, instead, challenging. For instance, in the beginning of the analysis phase, I measured the frequency with which participants mentioned certain transmission paradigms and I focused on quantitative comparisons (e.g., how many times the mother transmitted behaviour x, versus how many times behaviour x was transmitted by a peer). Yet, the purpose of the study was to explore cultural information flow in depth and understand its processes, and, therefore, I decided to spend more time familiarising myself with the data. During this, I was able to focus on the individual point of view of my participants and rearrange my data units into more appropriate categories, all of which were then allocated to one of three themes corresponding to the theoretical framework in which I was interested (see Qualitative study; Results).

Upon reflection, I am optimistic that my PhD has equipped me with new skills, necessary for my academic career. I am particularly grateful for the methodological skills I have acquired; from learning how to design a valid study in order to answer specific research questions, to practising different analytic approaches, such as mixed-methods analysis and thematic analysis.

4 Avenues for Future Research

In this section I will present and discuss new avenues for future research inspired by both the methodological challenges we encountered and the new ideas arising from our findings.

4.1 Turning challenges into future research

When faced with methodological challenges, the primary course of action is to seek the solutions and apply them. In the case of this thesis, I am optimistic that most challenges were appropriately met. In the few cases where this was not achieved, I believe that the challenges we met can be used to provide directions for future research.

First, regarding the recruitment of participants, it would be interesting to run the first experiment (Language vs Demonstration study) with all participants recruited in similar conditions, preferably in a lab. Although time requirements restricted this in the case of our study, providing a degree of control of the confounding variables we inevitably introduced (e.g., environment, time of day etc.) could lead to stronger results. In addition, it would mean that the study could be reproduced more reliably, perhaps enabling reliable cross-cultural comparisons. These would be beneficial to the literature, as individuals from different cultures acquire information differently (Chiu, 1972). Therefore, they would, potentially, display different cultural transmission patterns (Mesoudi, Magid, & Hussain, 2016), such as more frequent overimitation of linguistically transmitted behaviour in adulthood than in childhood, as previous studies have shown (Berl & Hewlett, 2015; McGuigan et al., 2011a, 2007; McGuigan & Whiten, 2009; Moraru et al., 2016).

Second, it would be advantageous to run the Onward Transmission lab study with more participants, to collect more data per condition. This would, potentially, also minimise the influences of random errors on the results and allow for more accurate predictions (Emerson, 2015). Nonetheless, it is noteworthy that our hypotheses were successfully tested, in that the research design we have constructed for investigating onward transmission was effective and efficient to do so. Despite the size of our sample, our analysis allows for little to no doubt when it comes to our most essential finding: the context-congruence bias. This leads me to believe that future research could either employ our design or adapt it to test new hypotheses with confidence in its operation.

Third, I believe that the richness of the data collected during the final study (Qualitative study) points to the necessity of a mixed-methods (i.e., quantitative and qualitative) approach to exploring cultural information flow in the real world. Although this was not feasible during my PhD (due to time constraints), I am confident that future research can benefit greatly from combining quantitative and qualitative methods, e.g., by using interview data to understand the reasoning of participant behaviour during solving a task, or including observational data that

record participant reactions while learning different variants (as in the Onward Transmission lab study) to explain what they will later on deploy. Previous studies that have adopted this approach managed to gain a deeper understanding of phenomena such as tool innovation (Lew-Levy, Pope, Haun, Kline, & Broesch, 2021), while also providing the quantitative data to justify their qualitative findings (Bartholomew & Brown, 2012). I would, however, stress the importance of analysing qualitative data carefully, and with a clear perspective of the goal: understanding, not measuring.

4.2 New ideas

4.2.1 'Overimitation' and onward transmission

In addition to these, this thesis presents new ideas that point to several possible avenues for future research. These have been extensively discussed within each of the study Chapters (2, 3, and 4) but I believe it is important to note the general ideas when all our findings are considered combined.

It has previously been found that the likelihood that learners will acquire information is influenced by the transmitter's status (McGuigan, 2013), position of authority (Reyes-Garcia et al., 2008), age (Henrich & Gil-White, 2001; Wood et al., 2016), knowledge (Henrich & Gil-White, 2001), and success (Reyes-Garcia et al., 2008). This information may comprise of both causally relevant and irrelevant elements. By extension, overimitation, a complex learning mechanism, can also be influenced by characteristics of the transmitter such as the above (Hoehl et al., 2019; Wood et al., 2012). In this thesis, we have also provided support for the position that overimitation (i.e., a mechanism operating during acquisition) can be influenced by age, but also by language and, even, by the cultural background of the learners (e.g., there appears to be a developmental *decrease* in the overimitation tendencies of Cypriot individuals, contrary to the *increase* found with British participants; see cited studies in The Language vs Demonstration study). We have also shown that the characteristics of a model may bias what learners transmit onward to others. Finally, we have presented the hypothesis that the context of acquisition may be associated with the context of onward transmission and that this association can affect and predict what individuals transmit onward to new learners, an effect we have termed 'context-congruence'.

Based on the above, one might predict that individuals would be more likely to overimitate an expert-experimenter than a peer-confederate. Our study (Onward Transmission lab study),

however, did not examine what the participants acquire for themselves after having observed an expert and a peer demonstrate two different variants of behaviour, as it focused more on what they transmit onward to others. In fact, we did not explicitly include causal relevance as a variable in the study: causally irrelevant and relevant elements were not controlled or included in the design.

Future Research Question 1: Do participants transmit onward the causally irrelevant elements of behaviour to new learners even if they do not overimitate themselves?

Considering the above, it would be interesting to investigate what would learners who have observed causally relevant actions (as per in our Onward Transmission lab study) along with causally irrelevant ones during acquisition transmit onward to other learners. To that end, a study would need to examine both the behavioural elements produced by participants after they had observed them (acquisition phase) and the behavioural elements they transmit to other learners (onward transmission phase).

We have scarce (if any) data to form hypotheses with some confidence, so I can only assume that, most likely, participants will tend to transmit onward more causally irrelevant behavioural elements than the ones that they perform during the acquisition phase. In The Qualitative study, I discuss the phenomenon of parents acquiring a peer's more 'modernised' and efficient variants of a behaviour and, yet, transmitting onward to their children the variants that may be causally irrelevant. On the other hand, some of the parents in the sample also appear to perform the causally opaque variants even when their children are not observing or learning from them (i.e., absence of an onward transmission context). Thus, it may be that individuals who will overimitate will transmit onward the causally irrelevant elements they learn themselves, leading to an almost equal number of irrelevant elements overimitated and transmitted onward.

A study that shows the connection between overimitation during acquisition and onward transmission of causally irrelevant behavioural elements would be a great addition to the literature. We know that overimitation enables the high-fidelity transmission of information across generations, which supports cumulative cultural evolution (Tennie et al., 2009; Tomasello, 1994, 1999b). We are, also, beginning to understand *whom*, *what*, *when* and *why* we copy (Atkinsson et al., 2012; Chudek et al., 2012; Henrich & Broesch, 2011; Kendal et al., 2009; McGuigan, 2012; Price et al., 2017; Wood et al., 2016, 2013). Yet, we still do not know how traditions, usually comprising of both causally relevant and irrelevant elements, are

conserved if in our overimitation experiments several causally irrelevant elements are lost along the transmission chains.

As mentioned above, it could be that transmitters, though not acquiring causally irrelevant behavioural elements for themselves, will tend to transmit these onward to other learners. Although I do not think that previous overimitation chain studies (e.g., Flynn, 2008; Flynn & Whiten, 2008; McGuigan & Graham, 2010; Nielsen et al., 2012) can be used to infer a connection between overimitation and onward transmission – as participants in those studies do not, usually, perform their actions for a learner to observe (instead, the observer enters the room while the participant is focused on completing the task, with no explicit instruction that they were about to "teach" or "show" something to another person and only having been instructed to "have a go" or" try it" for themselves) and, so, the context of onward transmission is rendered obsolete – they can be used to provide guidance as to the variables that need to be controlled (e.g., instructions provided, participant age, etc.), the properties of the materials that can be used (e.g., transparent versus opaque boxes and the effects of each), the effects of conventional versus instrumental actions and so on.

Future Research Question 2: Is the onward transmission of causally irrelevant elements of behaviour to new learners influenced by the context-congruence bias?

The results of the Onward Transmission in the lab study and the Qualitative study demonstrate the effects of a context-congruence bias during transmission. An interesting future step could be to examine whether individuals who observe causally-irrelevant actions in one acquisition context only (either peer-to-peer or expert-to-peer, but not both), then go on to transmit the irrelevant actions only in the congruent context (when teaching a peer or a novice respectively), but not in the incongruent one (individuals do not perform the peer's causally irrelevant actions for a novice to observe, or they do not perform the expert's causally irrelevant actions for a peer to observe). If this is the case, it could have great implications for cultural evolutionary theory, as it would provide a predictor influencing *when* casually irrelevant actions are conserved and when they cease to exist in a population.

This question can be investigated by including an equal number of causally irrelevant elements as causally relevant ones (overimitation) and incorporating the two-way action approach (dichotomous trait). In a task similar to ours (in which participants learned two different strategy variants to solve a task, one from an expert and one from a peer, and they were, then, asked to transmit one onward either to a peer or to a novice; Onward Transmission lab study),

one would need to add the intermediate step of checking what the participants acquire (by, e.g., having them write down a solution) before asking them to transmit one of the variants onward. this step could also be achieved by inviting the participants back to the lab after a few days, asking them to solve the task, and recording the strategy variant they used.

Future Research Question 3: Does age affect the onward transmission of causally irrelevant elements of behaviour to new learners?

In the literature, there still exists a gap regarding the developmental changes in the tendency to overimitate (e.g., Berl & Hewlett, 2015; McGuigan & Graham, 2010; McGuigan et al., 2011a). The Language vs Demonstration study does not support the idea that overimitation tendencies increase developmentally, as the child participants in our experiment overimitated significantly more actions than the adult ones in some conditions, whereas the reverse was not found in any condition.

However, we do not know what would happen were we to ask the adult participants in our study to transmit onward the behaviour for another participant to learn how to solve the same task. Would they, then, have transmitted the causally irrelevant actions that they had omitted from their output? And, if yes, would they tend to transmit onward more causally irrelevant actions than children would? Cultural transmission is achieved via overimitation (Berl & Hewlett, 2015; Hoehl, Zettersten, Schleihauf, Grätz, & Pauen, 2014; Lyons et al., 2011), as well, but it is not restricted in the acquisition of information. In order to assess how overimitation is connected with cultural evolution, studies need to incorporate the facet of onward transmission. It would be necessary, of course, to include onward transmission in the term 'overimitation', which is currently described as a learning mechanism. For instance, would we consider that participants who transmit onward causally irrelevant actions overimitate, even if they do not perform these at an intermediate stage of acquisition?

Answering such questions could help us determine how age affects overimitation. Naturally, future research would need to include more age groups than merely young children and adults. It would be beneficial to be able to make comparisons between infants, young children, pre-adolescents, adolescents, young adults and so on, as the age of individuals may affect the onward transmission of certain variants (as shown in our Qualitative study, where, e.g., older siblings transmit horizontally acquired variants to siblings and younger ones transmit vertically acquired ones onward to their siblings).

4.2.2 Assessing the effectiveness of the mother-transmitter

Future Research Question 4: Can matrilineality explain the higher conservation of the mother's cultural variants in comparison to the father's?

In The Qualitative study we discuss a new hypothesis formed by our data which would be interesting to examine: the different degrees of the effectiveness of the mother as a cultural transmitter and of the father/husband. Based on our results (which, albeit, arise from a small dataset) we can assume that, in some cases (such as in that of housework-related behaviour and attitudes), the stronger effects of the mother-transmitter may explain how some cultural variants get replaced by others (e.g., the husband adopts his wife's variant over those of his parents and he, also, transmits onward the wife's variants). If that is the case, this could have implications for how some cultural traditions – specifically, those vertically transmitted to the mother – are conserved within families via their vertical transmission, while others cease to exist.

Nevertheless, we recruited Greek-Cypriot participants and Cyprus is a matrilineal society (Anthias, 1989; Christodoulides, 1990). A plausible explanation, therefore, for our results would be the cultural background of the participants. Future research could collect similar data from participants of different societies to explore how matrilineality may shape the familial traditions. Although our data suggests that our results are only due to matrilineality, one cannot simply suggest that without examining how participants from patrilineal societies behave.

Apart from cultural background, the type of tasks in this study (housework) could have influenced the efficiency of the mother-transmitter. Women are, generally, found to be expected to be responsible for housework (Lachance-Grzela & Bouchard, 2010; Lee et al., 2018; Thébaud, Kornrich, & Ruppanner, 2021) and to take up most of it (Bartley et al. 2005; Lee 2005; Askari et al. 2010). Perhaps, then, they may wield more power when it comes to assigning tasks for the other members of their household to do and to deciding in what way they do them. It would be interesting to examine how information flows in other spheres, such as work, hobbies, and, in general, activities outside the home, where the father could be more influential for the children and the spouse.

5 Conclusion

If I were to sum up the most notable implication of this thesis in a sentence, it would be this: "To advance cultural evolutionary theory, we need to understand cultural transmission by studying it in its entirety". I have stated in Chapter 1 that this PhD sets out to investigate the cultural transmission process – particularly some of its unexamined and underexplored aspects – with the overall aim of advancing cultural evolutionary theory. I am confident that it addresses important gaps in the theory, especially around the biases affecting the selectiveness of individuals during transmission and specifically – or, perhaps, most importantly – during onward transmission. I believe that a clearer focus on incorporating onward transmission in future research designs can illuminate unanswered questions and bridge current inconsistencies, such as the developmental evolution of overimitation tendencies. Furthermore, I am hopeful that my thesis illustrates the advantages of implementing different methodologies and the necessity of a unifying framework to study cultural evolution.

As a closing remark, I would like to note a simple and straightforward quote by Cavalli-Sforza and Feldman, who have inspired much of my own and the cited research above: "The evolution of traits that are cultural depends ultimately on the way in which such traits are transmitted among individuals within a generation, and between generations" (1981; p. 7). I believe that their ideas should be implemented in a broader spectrum of the theory, particularly one that accounts for both facets of cultural transmission, and I am optimistic that my research, along with that of other scholars, sets a precedent for doing so.

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Publications

A version of the first study (Chapter 2) of this thesis has been published in Humanities and Social Sciences Communications (Nature), with input from Dr Monica Tamariz and Dr Nicola McGuigan, and feedback from Dr Mioara Cristea.

The published manuscript can be accessed here:
https://www.nature.com/articles/s41599-021-00925-4#Abs1

Appendices

Appendix A (Chapter 2): List of innovations

- Push door to the side to open
- Insert blue side of rod
- Lift door to open
- Insert red side of rod
- Shake box in the air randomly
- Shake box from left side to right
- Lift box to face table
- Lift door up for ball to roll out
- Open and then close door by lifting
- Try to push door open with rod
- Rotate the box
- Lift box to roll ball out
- Rub rod to the side of the box
- Swing rod left-right in front of box
- Touch top of box
- Stir the air in front of box with rod
- Insert finger in the door
- Tap the box once
- Tap 3 times the box with hand
- Swipe rod on box
- Poke door with rod
- Push door upwards with rod
- Push door to side with rod
- Tap box with hand 5 times
- Swipe hand and then rod on one side of the box
- Swipe hand and then rod on one other side of the box
- Swipe hand on box
- Poke door with finger
- Look around the box

Appendix B (Chapter 2): List of actions performed by the control groups

(Rel = causally relevant, Irrel = causally irrelevant)

ADULTS:

- Slide door to the side with hand (Rel)
- Insert magnetic end of rod to take out the ball (Rel)
- Insert fingers inside the door (Irrel)
- Lift box to slide the ball out (Rel)
- Insert the Velcro side of rod to take out the ball (Rel)
- Slide door to the side using the rod (Rel)
- Lift the door up to open using hand (Rel)

CHILDREN:

- Lift the door up to open using hand (Rel)
- Insert the Velcro side of rod to take out the ball (Rel)
- Slide rod up and down on the side of the box (Irrel)
- Knock on the box using the rod (Irrel)
- Poke door using the rod (Irrel)
- Slide door to the side using the rod (Rel)
- Insert magnetic end of rod to take out the ball (Rel)
- Slide door to the side with hand (Rel)
- Insert fingers inside the door (Irrel)

Appendix C (Chapter 2): Post hoc pairwise comparisons for the significant interactions found in our GLMER analyses

1. Post-hoc pairwise comparisons for the **Transmission Mode * Age** interaction in model:

   RETENTION ~ Causal Relevance * Transmission Mode * Age + (1 | Participant) + (1 | Action)

CONTRAST	ODDS RATIO	SE	Z RATIO
Verbal-Adult / Demo-Adult	0.34	0.18	-2.04
Verbal-Adult / Verbal-Child	0.44	0.22	-1.66
Verbal-Adult / Demo-Child	0.46	0.24	-1.5
Demo-Adult / Verbal-Child	1.31	0.66	0.53
Demo-Adult / Demo-Child	1.37	0.72	0.6
Verbal-Child / Demo-Child	1.05	0.52	0.1

2. Post-hoc pairwise comparisons for the **Causal Relevance* Age** interaction in model:

   RETENTION ~ Causal Relevance * Transmission Mode * Age + (1 | Participant) + (1 | Action)

CONTRAST	ODDS RATIO	SE	Z RATIO
Adult-Irrel / Child-Irrel	0.68	0.32	-0.81
Adult-Irrel / Adult-Rel	0.19	0.13	-2.46
Adult-Irrel / Child-Rel	0.17	0.12	-2.52
Child-Irrel / Adult-Rel	0.28	0.18	-1.96
Child-Irrel / Child-Rel	0.24	0.15	-2.27

Adult-Rel / Child-Rel	0.88	0.39	-0.28

3. Post-hoc pairwise comparisons for the **Causal Relevance * Transmission Mode * Age** interaction in model:

RETENTION ~ Causal Relevance * Transmission Mode * Age + (1 | Participant) + (1 | Action)

CONTRAST	ODDS RATIO	SE	*Z* RATIO
Verbal-Adult-Irrel / Demo-Adult-Irrel	0.34	0.25	-1.49
Verbal-Adult-Irrel / Verbal-Child-Irrel	0.21	0.15	-2.25
Verbal-Adult-Irrel / Demo-Child-Irrel	0.74	0.51	-0.43
Verbal-Adult-Irrel / Verbal-Adult-Rel	0.19	0.15	-2.06
Verbal-Adult-Irrel / Demo-Adult-Rel	0.06	0.06	-3.00
Verbal-Adult-Irrel / Verbal-Adult-Rel	0.17	0.15	-2.04
Verbal-Adult-Irrel / Demo-Child-Rel	0.05	0.05	-3.16
Demo-Adult-Irrel / Verbal-Child-Irrel	0.62	0.40	-0.74
Demo-Adult-Irrel / Demo-Child-Irrel	2.22	1.48	1.19
Demo-Adult-Irrel / Verbal-Adult-Rel	0.56	0.45	-0.72
Demo-Adult-Irrel / Demo-Adult-Rel	0.19	0.15	-2.10
Demo-Adult-Irrel / Verbal-Adult-Rel	0.52	0.42	-0.82
Demo-Adult-Irrel / Demo-Child-Rel	0.16	0.14	-2.13
Verbal-Child-Irrel / Demo-Child-Irrel	3.56	2.19	2.06
Verbal-Child-Irrel / Verbal-Adult-Rel	0.90	0.66	-0.14

Verbal-Child-Irrel / Demo-Adult-Rel	0.30	0.24	-1.51
Verbal-Child-Irrel / Verbal-Child-Rel	0.83	0.56	-0.28
Verbal-Child-Irrel / Demo-Child-Rel	0.26	0.20	-1.71
Demo-Child-Irrel / Verbal-Adult-Rel	0.25	0.20	-1.75
Demo-Child-Irrel / Demo-Adult-Rel	0.09	0.07	-2.92
Demo-Child-Irrel / Verbal-Adult-Rel	0.23	0.18	-1.86
Demo-Child-Irrel / Demo-Adult-Rel	0.07	0.06	-3.31
Verbal-Adult-Rel / Demo-Adult-Rel	0.34	0.21	-1.73
Verbal-Adult-Rel / Verbal-Child-Rel	0.92	0.53	-0.14
Verbal-Adult-Rel / Demo-Child-Rel	0.28	0.18	-1.98
Demo-Adult-Rel / Verbal-Child-Rel	2.73	1.74	1.58
Demo-Adult-Rel / Demo-Child-Rel	0.84	0.58	-0.25
Verbal-Adult-Rel / Demo-Child-Rel	0.31	0.20	-1.82

4. Post-hoc pairwise comparisons for the **Generation[1] * Age** interaction in model: **CUMULATIVE IMPROVEMENT ~ Generation * Transmission Mode * Age + (1 | Chain)**

CONTRAST	ODDS RATIO	SE	*Z* RATIO
Gen2-Adult / Gen2-Child	1.8	0.44	2.38

[1] Note that Generation is a numeric variable and, therefore, we only have its second level (after centring it) in the contrast.

5. Post-hoc pairwise comparisons for the **Generation * Transmission Mode * Age** interaction in model:

CUMULATIVE IMPROVEMENT ~ Generation * Transmission Mode * Age + (1 | Chain)

CONTRAST	ODDS RATIO	SE	Z RATIO
Verbal-Adult-Gen2 / Demo-Adult-Gen2	2.09	0.82	1.89
Verbal-Adult-Gen2 / Vebal-Child-Gen2	3.78	1.40	3.60
Verbal-Adult-Gen2 / Demo-Child-Gen2	1.78	0.72	1.45
Demo-Adult-Gen2 / Verbal-Child-Gen2	1.81	0.52	2.07
Demo-Adult-Gen2 / Demo-Child-Gen2	0.85	0.28	-0.48
Verbal-Child-Gen2 / Demo-Child-Gen2	0.47	0.15	-2.44

Appendix D (Chapter 3): Design

In order to control our confounding variables, we counterbalance the strategy variant – counting-the-gears (strategy A) versus alternate-directions (strategy B) – and the order of the presentation of the two strategies to the participants (expert's first, peer's last, versus peer's first, expert's last) all participants were allocated to one of two different subgroups, so that each subgroup had sixteen participants (see also table 1):

1.a. Expert-Peer-Novice: All sixteen participants in this group were asked to *teach* a *novice* (a confederate) how to solve the problem. Eight of the participants in this group were first taught by the expert strategy A, and then they were shown by a peer strategy B. The remaining eight participants were first taught by the expert strategy B, and then they were shown by a peer strategy A.

1.b. Peer-Expert-Novice: All sixteen participants in this group were asked to *teach* a *novice* (a confederate) how to solve the problem. Eight of the participants in this group were first shown by a peer strategy A, and then they were taught by the expert strategy B. The remaining eight participants were first shown by a peer strategy B, and then they were taught by the expert strategy A.

2.a. Expert-Peer-Peer: All sixteen participants in this group were asked to *show* a *peer* (a confederate) how to solve the problem. Eight of the participants in this group were first taught by the expert strategy A, and then they were shown by a peer strategy B. The remaining eight participants were first taught by the expert strategy B, and then they were shown by a peer strategy A.

2.b. Peer-Expert-Peer: All sixteen participants in this group were asked to *show* a *peer* (a confederate) how to solve the problem. Eight of the participants in this group were first shown by a peer strategy A, and then they were taught by the expert strategy B. The remaining eight participants were first shown by a peer strategy B, and then they were taught by the expert strategy A.

Table 1: This table presents the two conditions and their subgroups, in which the participants were allocated. In Condition 1, the participant assumes the role of an expert, and is asked to teach a strategy to a novice. In condition 2, the participant assumes the role of a peer, and is asked to show a strategy to a peer. The groups within each condition are formed to counterbalance the strategy variants and the order of presentation to the participant.

	CONDITION 1		CONDITION 2	
	Group a	Group b	Group a	Group b
Phase 1	Expert (Experimenter) teaches strategy A (or B)	Peer (Confederate 1) shows strategy A (or B)	Expert (Experimenter) teaches strategy A (or "B)	Peer (Confederate 1) shows strategy A (or B)
Phase 2	Peer (Confederate 1) shows strategy B (or A)	Expert (Experimenter) teaches strategy B (or A)	Peer (Confederate 1) shows strategy B (or A)	Expert (Experimenter) teaches strategy B (or A)
Phase 3	Participants are asked to teach a strategy to a novice (Confederate 2).		Participants are asked to show a strategy to a peer (Confederate 2).	

Appendix E (Chapter 4): List of topics/guiding questions covered within each interview

- How many hours a day would you say you spend at home?
- What do you typically do in those hours?
- Would you say that you do any housework? Why/why not?
- How much time do you spend doing housework? What exactly do you do?
- Why did/do you do those specific things around the house?
- Did/do your parents spend time doing housework? What did/do they do? What did/does your mother/father do to help around the house?
- Why did/does your mother do the things she did/does? How did/does she feel about doing housework?
- Why did/does your father do the things he did/does?
- Why do you help around the house? How does doing housework make you feel? Is doing housework fun? Why/why not?
- Would you prefer it if you didn't do any/parts of housework? Why/why not?
- What would you rather stop doing around the house? What do you enjoy doing around the house?
- Did/do your children help/do you think your children will help with the housework? What did/does each one of them typically do?
- Will you/do you/did you make an effort to ensure that your children see you doing … (each of the specific things they mentioned)?
- At what age did your children start helping around the house? How? Did they do more as they got older? What?
- At what age did you start helping around the house? How? Did you do more as you got older? What?
- How did your children start doing work around the house? What kind of work?
- Do you think children should help around the house? Why/why not? (If yes) at what age? Why?
- Do you feel it is important for children to do housework?
- Do you think everyone in the house should do housework? (If yes) why? Is it important? (If not) who shouldn't and why?
- Where did you learn how to do …? How? When? From whom?

- What kinds of products do you usually use? How were you introduced to these (or by whom)?
- How do you … (every activity they had mentioned)? Who taught you how to do that? How did/does that person do it?
- Do you feel like the work is equal for everyone? Should it?
- Is the distribution of work in your family similar to that of other families? How is it similar/different? Why do you say it is?

Appendix F (Chapter 4): Observation Log (one completed for each of the Family A members)

Participant ID: (e.g., Mother A)				
SPACE	**ACTIVITY**	**PRODUCTS**	**TIME SPENT**	**NOTES**
Bathroom	Toilet cleaning	(e.g., chlorine, Tic-tac...)	(e.g., 65 minutes)	(e.g., first scrubs inside…)
	Bathtub/Shower scrubbing			
	Sink Cleaning			
	Vacuuming			
	Mopping			
	Window cleaning			
Bedroom	Make Bed			
	Tidy up			
	Vacuuming			
	Mopping			
	Dusting			
	Ironing			
	Window Cleaning			
Kitchen	Dishwasher loading			
	Dishwasher unloading			
	Pans handwashing			
	Dishes/glasses /cutlery handwashing			
	Countertop (disinfection)			
	Cabinets (Dusting)			

	Cooking			
	Table Setting			
	Table cleaning (after meal)			
	Table cleaning (dusting)			
	Oven scrubbing and cleaning			
	Hob cleaning			
	Vacuuming			
	Mopping			
	Window cleaning			
Living Room	Tidying up			
	Dusting			
	Vacuuming			
	Mopping			
	Window cleaning			
Yard/Outside	Pet space cleaning			
	Pet feeding			
	Dog bathing			
	Sweeping			
	Plant watering			
	Window cleaning			
	Mopping			
	Furniture dusting			
	Plant maintenance			