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Top-down Influences on Imitation: Investigating Cognitive Load

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TABLE OF CONTENTS

Top-down Influences on Imitation: Investigating Cognitive Load

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Top-down Influences on Imitation: Investigating Cognitive Load

Imitation is a perceptual-motor coordination that allows individuals to match their own movements to those they observe in others (Heyes & Bird, 2008; Liepelt, Cramon, & Brass, 2008; Liepelt, Prinz, & Brass, 2010). To copy an observed action accordingly, the actor must execute a translation of a complex dynamic visual input pattern into motor commands. As complex as this may sound, humans are surprisingly successful in those translations. They are capable of imitating various kinds of actions, from simple to complex, without making major mistakes. For instance, individuals automatically imitate a wide range of behaviours from simple mannerisms like foot waggling and nose rubbing, facial expressions and postures that may not serve the achievement of a specific goal (Chartrand & Bargh, 1999; Chartrand, Maddux, & Lakin, 2005), to more complex, rather goal-focused actions (Shin, Proctor, & Capaldi, 2010; Wohlschläger, Gattis, & Bekkering, 2003).

The extent to which people imitate each other does not occur invariantly but is rather subject to several factors that influence the focus on certain aspects of the observed act, such as movements or goals. For example, goal focus was enhanced when goal objects were present (Wohlschlager & Bekkering, 2002) which facilitated goal-directed imitation (emulation). Conversely, when a model was temporally or spatially near more literal imitation was facilitated (Hansen, Alves, & Trope, 2016). Findings such as these suggest that a number of factors can modulate imitative faculties. Past research demonstrated that if working memory resources are depleted, selective attention is enhanced leading individuals to focus on the task relevant dimension whilst neglecting task irrelevant dimensions. In this study, we investigated how limited working memory capacities may influence imitation. In a study that directed attention at imitative behaviour involving a goal aspect (imitation and emulation), we predicted that high cognitive load would deplete attentional resources and thus influence the exactness of imitating a model in an adverse way. In particular, we tested the hypothesis that high cognitive load would reduce literal imitation (reduced accuracy of movement kinematics) in favor of emulation.

Theoretical Background

Imitation

Imitation, as a type of social learning, plays a crucial role in skill acquisition (Avikainen, Wohlschläger, Liuhanen, Hänninen, & Hari, 2003; Brass & Heyes, 2005; Wohlschlager & Bekkering, 2002). It allows skill knowledge and behaviour to be transmitted between two agents, bypassing the laborious trial-and-error learning procedure

(Wohlschläger et al., 2003). The transmission happens horizontally across the population as well as vertically down to the next generation (Ramachandran, 2000). Therefore, imitation plays a fundamental role in human evolution. Besides skill learning, imitation fosters liking and fulfils further important social functions such as language acquisition, socialization and enculturation (Brass & Heyes, 2005; Ramachandran, 2000; Wohlschläger & Bekkering, 2002). Given the functional significance of the imitation phenomenon, it is important to understand the skill in as much detail as possible. However, the mechanisms that underlie this phenomenon are yet to be fully discovered.

Given that observing another individual's movements does not provide us with any information of the underlying motor activation of the action, but rather the external consequences of that activation, how does the observer's motor system know which muscles to activate in order to reproduce the action? This missing link is widely known as the 'correspondence problem' (Brass & Heyes, 2005).

A theoretical solution to this problem was postulated over 100 years ago by William James (1890; as cited in Shin et al., 2010) who proposed the ideomotor theory. James stated that the mere thought of an action is enough to induce voluntary movements. The common coding theory specifies James idea in more detail by describing a link between perceptual and motor representations through shared representations (a common code) (Prinz, 1984). The contemporary ideomotor theory incorporates previous knowledge and provides a useful framework for action planning (Shin et al., 2010), suggesting that actions are represented in terms of the sensory form of their effects. The generated sensory image activates the matching motor representation and thus allows us to re-enact the observed action with ease. An activation of an effect image may be generated exogenously, by perceptual induction, or endogenously, by intentional induction (Hansen et al., 2016).

Perceptual and Intentional Induction - Mimicry and Emulation

Perceptual induction corresponds to mimicry, which describes the exact copying of low-level kinematics without necessarily sharing a common goal. Research has demonstrated that sharing a common goal is not a necessary prerequisite of imitation (Genschow & Florack, 2014; Genschow, Florack, & Wänke, 2013). For example, watching a video of an athlete lifting a barbell versus pushing a barbell led to an increased drink intake for the viewer solely due to the compatible movement paths. Intentional induction, on the other hand, corresponds to emulation, where the underlying intentions of an observed action are inferred and the observer aims to reproduce the action goal, which may be achieved through different movements. Interestingly, intentional induction allows individuals to imitate anticipated actions even before they have been observed (Genschow & Brass, 2015). Lastly, imitation can be viewed as an umbrella term that describes the combination of mimicry and emulation. Imitation by definition is the copying of movements in order to achieve the same end state.

Evidence for the idea of shared representations has been offered by different fields of research. Single cell recordings in the premotor area F5 of macaque monkeys led to the revolutionary discovery of mirror neurons, cells that are active both during the observation and the execution of an action (Di Pellegrino, Fadiga, Fogassi, Gallese, & Rizzolatti, 1992). Functional Magnetic Resonance Imaging (fMRI) provided evidence for a similar system in humans (Iacoboni et al., 1999). During an imitation task, increased activity was detected in the left inferior frontal cortex (Broca’s area, Brodmann’s area 44, 45), an area believed to be the human equivalent to the monkey’s pre-motor area F5. Iacoboni et al. (1999) referred to this idea as direct matching. Direct matching has also been observed in behavioural studies in the scope of the stimulus-response compatibility (SRC) paradigm (Brass, Bekkering, & Prinz, 2001; Brass, Bekkering, Wohlschläger, & Prinz, 2000; Heyes, Bird, Johnson, & Haggard, 2005), where the sheer observation of an action facilitates the execution of the same action. For example, in an imitation-inhibition task (Brass et al., 2001; Brass et al., 2000), participants were presented with a video of a model either lifting the index or middle finger and instructed to respond with either a compatible or an incompatible finger movement in respect to a number displayed on the screen. A common finding is that observing compatible movements results in faster response reactions. Therefore, direct matching has the ability to explain perceptual induction.

In regards to intentional induction, Liepelt et al. (2008) elegantly demonstrated that inferred action goals can trigger direct matching effects as well. In the experiment, participants watched a video of finger-lifting movements in which the full movement was either prevented by a clamp or the model performed only micro-movements as if there was a clamp. Only when the clamps were present, an interpretive context was provided and the action goal (lifting the finger) could be inferred, resulting in faster reaction times. Furthermore, the researchers (Liepelt et al., 2008) provided clear evidence for a top-down modulation of imitation through intention attribution, where inferred intentions modulated motor-priming effects. Direct-matching effects were significantly smaller when observed movements were passively generated by a pulley device lifting the fingers artificially than for intended movements. The same effects were shown when solely the participant’s interpretation of an action was changed by mere instruction. Consequently, the findings indicate that both action perception (perceptual induction) and the inference of action goals or the attribution of intentions (intentional induction) can trigger direct matching effects and facilitate action execution (Hansen et al., 2016; Liepelt et al., 2008). An open question, however, is under which circumstances do individuals mimic, imitate or emulate?

Impacting Factors

One obvious factor that has a decisive influence on imitative behaviour is whether a goal object is present or absent (Wohlschlager & Bekkering, 2002). If the goal is ambiguous or absent, the movements itself become one's goal and are being imitated most precisely, resulting in mimicry. However, if the goal object is salient, attention is paid towards reproducing the goal correctly, often (but not always) at the expense of movements. Whenever a goal is pursued in imitation, we differentiate between the two types of social learning that include goal attainment in their definition; namely imitation and emulation. Experiments in the scope of the GOADI-Theory (Theory of Goal directed action; Wohlschläger et al., 2003) suggest that goal focus facilitates emulation over more literal imitation (Hansen et al., 2016). In one such experiment (Bekkering, Wohlschlager, & Gattis, 2000), children had to imitate ipsi- and contralateral hand movements performed by a model, with the movements directed towards target locations on the table. When the target locations were made salient by dots (goal-aspect), children made more hand mistakes than when the target locations were ambiguous. Similar results could be obtained in the so-called pen-and-cups task (Wohlschlager & Bekkering, 2002; Wohlschläger et al., 2003), where participants observe a model moving a pen into one of two coloured cups (object), using either the right or the left hand (effector), while grasping the pen with the thumb pointing up or down (grip). A typical observation is that adults make fewer cup errors than hand errors and fewer hand errors than grip errors (Avikainen et al., 2003; Leighton, Bird, Charman, & Heyes, 2008; Wohlschläger et al., 2003). Based on the assumption that the primary goal of each action is to place the pen into the correct cup, this cup < hand < grip error pattern was taken as support for goal-directed imitation in the debate about whether imitation, in general, was movement- or goal-directed. However, Leighton et al. (2010) were able to show that by changing which of the elements was coloured, the cup < hand < grip error pattern changed in favor of the most salient one. That is, for instance, if the model wore coloured gloves, the movements would become the primary goal resulting in a hand < cup < grip error pattern and so on. Those findings again reinforce the belief that goal focus provokes more emulation relative to literal imitation.

A recent study (Hansen et al., 2016) found psychological distance to be a factor that influences people's focus on movements versus goals and therefore moderates the degree of emulation versus literal imitation. The researchers manipulated action representation on a cognitive level by impacting whether the action was perceived as psychologically near or distant (both temporally and spatially distant). Psychological distance leads individuals to focus more on abstract features, like goals, whereas proximity emphasises incidental features, like movements. Indeed, findings show that psychological distance facilitated emulation; participants committed more hand mistakes when the model was distant, indicating that they used their own means to attain the goal. However, psychological proximity led to more literal imitation, where the goal was attained just as well, but more attention was paid towards reproducing movement-kinematics correctly.

The present paper aims to investigate whether there are further factors (besides psychological distance and goal focus) that influence the degree to which an individual engages in emulation versus more literal imitation. Past research has demonstrated that if attentional resources are limited, selective attention improves (Chajut & Algom, 2003). The remaining resources are committed to process the most dominant task dimension while task-irrelevant information suffers from reduced utilisation. Therefore, cognitive load may be a further factor that influences emulation versus imitation by enhancing goal focus.

Cognitive Load

Cognitive load can be defined as the amount of mental effort currently active in one's working memory (Sweller, Van Merrienboer, & Paas, 1998). The working memory is a system of limited capacity (Repovš & Baddeley, 2006); only a certain amount of information or a few elements can be dealt with at the same time without overloading capacities and decreasing processing effectiveness (Kalyuga, Ayres, Chandler, & Sweller, 2003). The most widely known limitation is that the short-term memory can only hold seven plus, minus two items at a time (Miller, 1956). A. D. Baddeley and Hitch (1974) designed the multi-component model of working memory in order to make sense of the functions of the working memory. The multi-component model consists of a central executive, two uni-modal storage systems: a phonological loop and a visuospatial sketchpad, with an extra component that was added later on, termed episodic buffer. By testing functional accounts of the model, the system has progressed from the notion of a simple passive short-term memory, that only serves the function of storing information, to an active system that also provides the basis for complex cognitive abilities (Repovš & Baddeley, 2006) such as imitation.

Available resources of the working memory need to be distributed amongst the different components of a task. Those resources are often described as attention (Engle & Kane, 2003), and as long as enough cognitive resources are available, attention can be distributed accordingly across the components and all aspects can be dealt with, with similar accuracy. If, however, there are too many components needing attention at the same time, the limited attention has to be distributed in one way or another. The distribution is accomplished by the central executive, which is also referred to as the active part of the system. According to Baddeley (1996) the central executive bears four basic capacities: the ability to focus, divide and switch attention, as well as the ability to relate short-term information to the information stored in the long-term memory.

The first evidence that working memory load affects imitation was provided by van Leeuwen, van Baaren, Martin, Dijksterhuis, and Bekkering (2009). Using an N-back task (0-back, 2-back) within Brass et al.'s (2000) finger imitation paradigm, the researchers tested imitative responses to finger versus spatial cues. They found that high working memory load increased error rates in general and speeded up response times to finger cues but not to spatial cues. The results suggest that imitation is a dominant response and executive function is needed to inhibit the spontaneous tendency to imitate.

Present Research

The present study aimed at exploring whether cognitive load influences which aspects of an observed action, movements or goals, individuals focus on when imitating.

The GOADI theory (Wohlschläger et al., 2003) suggests that when the imitator observes an action, they cognitively decompose the perceived act into separate aspects. However, due to capacity limitations, only a few aspects can be selected as goals. A hierarchical organisation of the selected goal aspects follows. The aspects are ordered accordingly to their functionality, which means, ends (objects or treatments of the object), if present, are more important than means (effectors or movement paths).

Following this logic, we suggest that if the working memory capacity is artificially reduced, attentional resources will not be sufficient to supply both movement- and goal aspects of the task. Since goals are supposedly more important than means and reduced resources are fully engaged by the most dominant task dimension, which is the goal aspect if made salient, movements will be the first element to receive less attention, which will result in relatively more emulation versus literal imitation. Furthermore, this also implies that if attentional resources are sufficient, both movements and goals can be executed with the same level of care.

A reduction of the working memory's capacity can be achieved in various ways. One example is the N-back task, which has frequently been shown to pose a vast and continuous load onto the working memory (Szmalec & Vandierendonck, 2007; van Leeuwen et al., 2009), leading to specific limitations of central cognitive processes. Another way to reduce working memory capacity is by applying time pressure. The application of time pressure introduces stress, which leads to more general restrictions of resources on different levels including perceptual, motor and cognitive functions (Engle & Kane, 2003). Task analysis of speed tasks strongly suggest that they tax executive attention, immediate memory and/or long-term memory retrieval functions (Conway, Cowan, Bunting, Therriault, & Minkoff, 2002; Conway, Kane, & Engle, 1999; as cited in Engle & Kane, 2003). Previous studies have shown that placing a heavy load on the central executive compromises the capacity to focus attention and impairs various complex cognitive tasks that require focused attention (Repovš & Baddeley, 2006). Furthermore, a study on social cognition showed that stress induces a differential deployment of attentional resources by enhancing the selectivity of attention towards task relevant dimensions (Chajut & Algom, 2003). Therefore, employing both memory load and time pressure in the same experiment allows to test how specific restrictions or more general restrictions on cognitive resources affect imitative processes.

To test the influence of cognitive load on imitative behaviour, we conducted a study in which we manipulated time pressure as well as working memory load within a task similar to the pen-and-cup task (Wohlschlager & Bekkering, 2002; Wohlschläger et al., 2003) and monitored their respective effects on movement- as well as goal-directed imitation separately. We hypothesise that individuals under high cognitive load commit more movement- than goal mistakes in an adapted version of the pen-and-cup task.

Method

Participants and Design

Fifty-seven right-handed undergraduate psychology students from the University of Ghent, Belgium, received partial course credit in exchange for their participation in the experiment. The age of the final sample ranged from 18 to 30 years (*M* = 20.35, *SD* = 3.92), 87.72% of which were female. A 2 (working memory load: high vs. low) x 2 (time pressure: high vs. low) x 2 (imitation: movement vs. goal) mixed design was applied, with time pressure being the between-subject factor and the other two variables acting as within-subject factors. All participants completed both of the two working memory conditions (low-/ high-load). As to whether they started with the low-load or the high-load condition was randomly assigned.

Procedure and Materials

The adapted pen-and-cup task was programmed with E-Prime® software (Schneider, Eschman, & Zuccolotto, 2002). The computerised task displayed a combination of a memory task and an imitation task, where the memory task wrapped around the imitation task. That is, participants were shown and had to remember either one or two one-digit numbers at a time (depending on the memory load condition; low-load vs. high load) while imitating a model's action and subsequently recall and enter the memorised number.

After being greeted and seated in front of a computer with a white Apple® ”QUERTZ”-keyboard, participants signed a form of consent (Appendix C). Four participants were tested at the same time in a computer room without noise pollution. The experimenter stayed in the room the whole duration, witnessing the procedure and recording any irregularities. The whole experiment consumed about 30-40 minutes of the student's time, whereas the actual task completion was generally accomplished within approximately 20-25 minutes. On the keyboards, four keys were marked with coloured stickers. The keys “C” and “M” were marked with orange-coloured stickers, whereas the keys “T” and “U” were marked with red- and black-coloured stickers, respectively. A short verbal instruction provided the respondents with an idea of what they would be faced with. Initiating the task, on-screen instructions appeared (Appendix B), informing the students that the task would consist of a combination of a memory- and an imitation task and that they would be given the opportunity to train each task separately first (memory task and imitation task), moving on to a combined training, before starting the actual trials.

The experiment was composed of four blocks; two low-cognitive load and two high-cognitive load condition blocks (working memory load), appearing in an interchangeable order. Before each block, there was at least one training block. Three training blocks prior to block 1 and block 2 (memory training block, imitation training block and both combined) and one training block (only the combined training block) prior to block 3 and block 4. This procedure introduced students to the task step by step, ensuring an adequate understanding.

To induce working memory load, but control for dual-task effects, the N-back task was applied in two difficulty versions; 1-back and 2-back. The first training block introduced the memory task (N-back task) as a simple memory and recall exercise of one-digit numbers. The block consisted of five trials. One trial was composed of five steps; a fixation cross, lasting for 500 ms, followed by a randomly chosen one-digit number (1-9), lasting for 500 ms also, followed by the question “What was the (second) last number?”. Participants then moved on to entering the number as well as receiving feedback on whether they had entered the correct number. The type of the training block (to recall the last or second last number) was adjusted as to whether the subject had been assigned to start the task with the low- or high load condition. They had to remember either one number at a time for the low-load condition or two numbers for the high-load condition. For the high load condition, participants were asked to recall the second last number, meaning the number that appeared in the previous trial.

In the second training block, the imitation task was introduced, with five trials also. The fixation cross was replaced with the text “press and hold ‘c’ and ‘m’”, which appeared for 500 ms, followed by two imitation pictures (500 ms each). The first picture displayed the starting position of an action, where the model pressed the orange stickered keys (“C” and “M”) with both their index fingers (Appendix D, Figure 3D). The second picture displayed the end position of the action, where the model had moved either their left or their right hand to press the red-marked or the black-marked key. The starting position was always the same, the end position was randomly chosen from the four possible hand-key-combinations (right or left hand used for pressing “T” or “U”) (Appendix D, Figure 4D - 7D). After those two pictures, a text appeared instructing participants to “Imitate now!”. Participants were instructed to imitate the action with the aim to get as many “Correct!” responses as possible. Participants received feedback only on their key presses, not on their choice of hands. This decision was based on the reasoning that both releasing a key as well as pressing a key could be considered movements. However, shifting the goal from a key press to the goal of receiving a “Correct!” response on the screen, allowed the differentiation between movement- (using a different hand than the model) and goal-errors (pressing a different key than the model).

The third training block combined the first two blocks (memory- and imitation task) imitating “real” trials. This block, again, consisted of five trials. Participants were instructed that they would be presented with a one-digit number that they had to remember during, and recall after, the imitation part. Depending on whether the first experimental block was going to be a low- or a high-load condition block, participants would train for the appropriate task (to remember either one number back – “What was the last number?”, or two numbers back – “What was the second last number?”). Before each trial, participants were reminded to return to the starting position by being presented with the text “press and hold ‘c’ and ‘m’”, which lasted for 500 ms. Participants were instructed that they had to keep pressed the orange-stickered keys during the number presentation as well as during the presentation of the two imitation pictures. Only after those two pictures had appeared, and once the caption “Imitate now!” was displayed, the believed to be appropriate key (“C” or “M”) had to be released and subsequently the believed to be appropriate target key (“T” or “U”) had to be pressed. After imitating, respondents were asked to recall and enter the number they had memorised and then to return to the starting position as quickly as possible before the next trial was to start. Feedback was provided only for the key presses of the imitation part. No feedback was provided for the number entry.

After the three training blocks, the first of four experimental blocks started. Participants went through four blocks of 36 trials each, resulting in 72 trials per working memory load condition and 144 trials in total. Each of the four hand-key combinations appeared nine times in each block. The order of the blocks was counterbalanced. The computer recorded which hand participants used (left or right), by recording which key they released (“C” for left and “M” for right) and whether participants pressed the same key as the model (“T” or “U”). Here, the task difficulty was increased; imitation pictures were speeded up to 50 ms per picture. Figure 1 depicts the sequence of one trial within an experimental block.

Before the second of the four blocks was initiated, participants were able to train for the other cognitive-load condition of the memory task (similar to training block 1) as well as the combined task (similar to training block 3), each with five trials. Prior to block 3 and block 4, students performed a quick training of the combined task (similar to training block 3) with four trials each. This procedure was to make sure that participants understood that the condition had changed. At the end of the experiment participants received a confirmation of participation needed for their course, were thanked and debriefed.

To introduce time pressure, the inter-trial times were varied between a low-time pressure and a high-time pressure group. In the high-time pressure group the trials would start automatically after 500 ms, whereas in the low-time pressure group participants were instructed that they are allowed to take small breaks between trials and that they would be able to initiate each trial themselves, whenever they were ready, by simultaneously pressing the “C” and “M” keys.

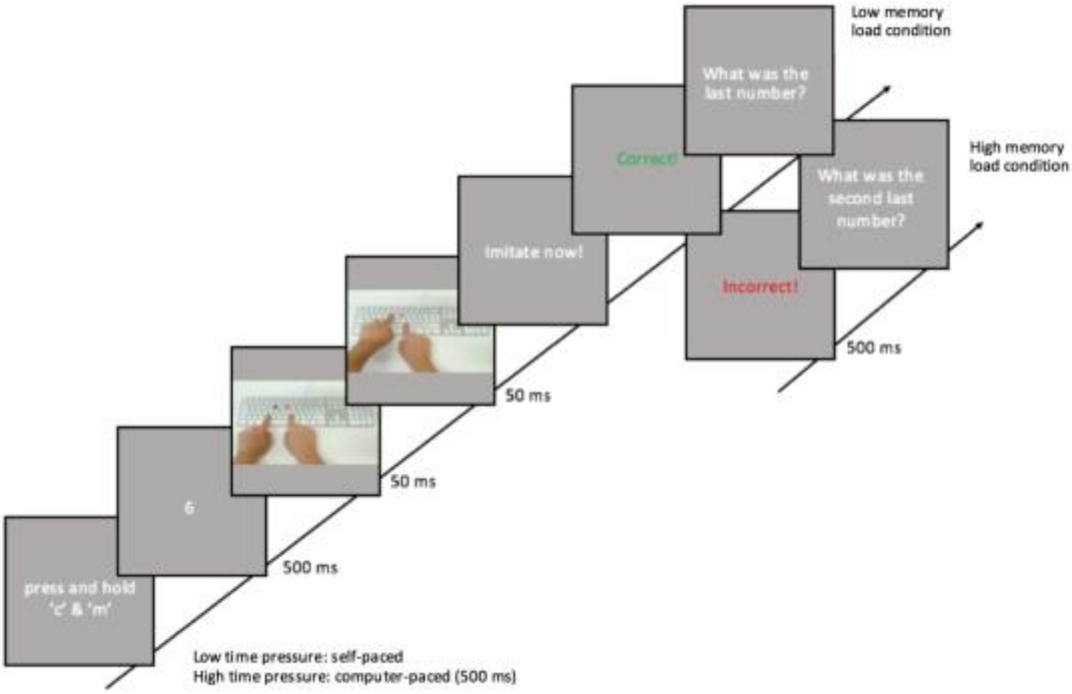

Figure 1. Sequence of a trial in the experimental block.

To prepare data for analysis, the dependent variables, hand errors and key errors, were computed in percentages. Hand errors were defined as the proportion of trials in which participants used a different hand than the model. For example, if the model had released the key "M" (right hand) and the subject, however, released the key "C" (left hand), a hand error would be recorded for this participant. Any key release other than "C" or "M" was considered a missing value and not an error. Key errors were defined as the proportion of trials in which participants pressed a different key to that of the model; for example, if the model pressed the key "T" and the participant, however, pressed "U". For the key presses, any other key press than the one the model had pressed was considered a goal error.

Results

To test our hypothesis, data were submitted to a 2 (cognitive load - memory: high vs. low) x 2 (cognitive load – time pressure: high vs. low) x 2 (hand vs. goal errors) mixed-design analysis of variance (ANOVA) with memory load and imitation acting as within-subject factors and time pressure acting as between-subject factor.

The analysis revealed two main effects for the within-subject test. Firstly, a main effect of imitation (error type) could be detected $F(1,55) = 23.44$, $p < .001$, $\eta_p^2 = .30$, implying that individuals committed more movement errors than goal errors. These results replicate previous findings of the pen-and-cup task (Avikainen et al., 2003; Bird, Brindley, Leighton, & Heyes, 2007; Leighton, Bird, & Heyes, 2010; Wohlschlager & Bekkering, 2002; Wohlschläger et al., 2003). Secondly, there was a main effect of memory load $F(1,55) = 20.55$, $p < .001$, $\eta_p^2 = .27$, indicating that memory load increased imitation errors in general, replicating previous findings on imitation and working memory load (van Leeuwen et al., 2009). The between-subjects test revealed a significant main effect of time pressure $F(1,55) = 10.88$, $p < .002$, $\eta^2 = .17$, again indicating that time pressure increased imitation errors in participants.

More important for the hypothesis, however, are the interactions. Neither the three-way interaction between imitation, working memory load and time pressure, $F(1, 55) = 0.06$, $p = .810$, nor the two-way interaction between imitation and working memory load, $F(1, 55) = 0.30$, $p = .586$, were significant. However, the analysis revealed an interaction effect of time pressure and imitation $F(1,55) = 13.66$, $p < .001$, $\eta_p^2 = .20$, implying that the psychological factor time pressure moderates the degree to which individuals imitate goals- versus movements.

Paired sample t-tests were used to follow up on the main effects as well as to clarify the interaction between time pressure and imitation. The main effect of imitation was found to only be true for high time pressure, but not for low time pressure. Under high time pressure, participants committed more hand mistakes (M = 17.61%, SE = 2.82) than goal mistakes (M = 2.98%, SE = .42), $t(27) = 5.02$, $p < .001$, $d = .95$ Conversely, when there was no time pressure, there was no statistically significant difference between the two forms of imitation; hand mistakes (M = 5.67%, SE = 1.82), goal mistakes (M = 3.74%, SE = .55), $t(28) = 1.06$, $p = .298$.

Subsequent independent samples t-tests confirmed that the effect was driven by hand mistakes. A significant difference was found between hand mistakes in the high time pressure condition and hand mistakes in low time pressure condition, $t(55) = 3.57$, $p < .001$, $d = .96$, whereas the difference between goal mistakes was non-significant, $t(55) = -1.11$, $p = .274$. By introducing time pressure, hand mistakes increased by 309%. Figure 2 illustrates the results graphically.

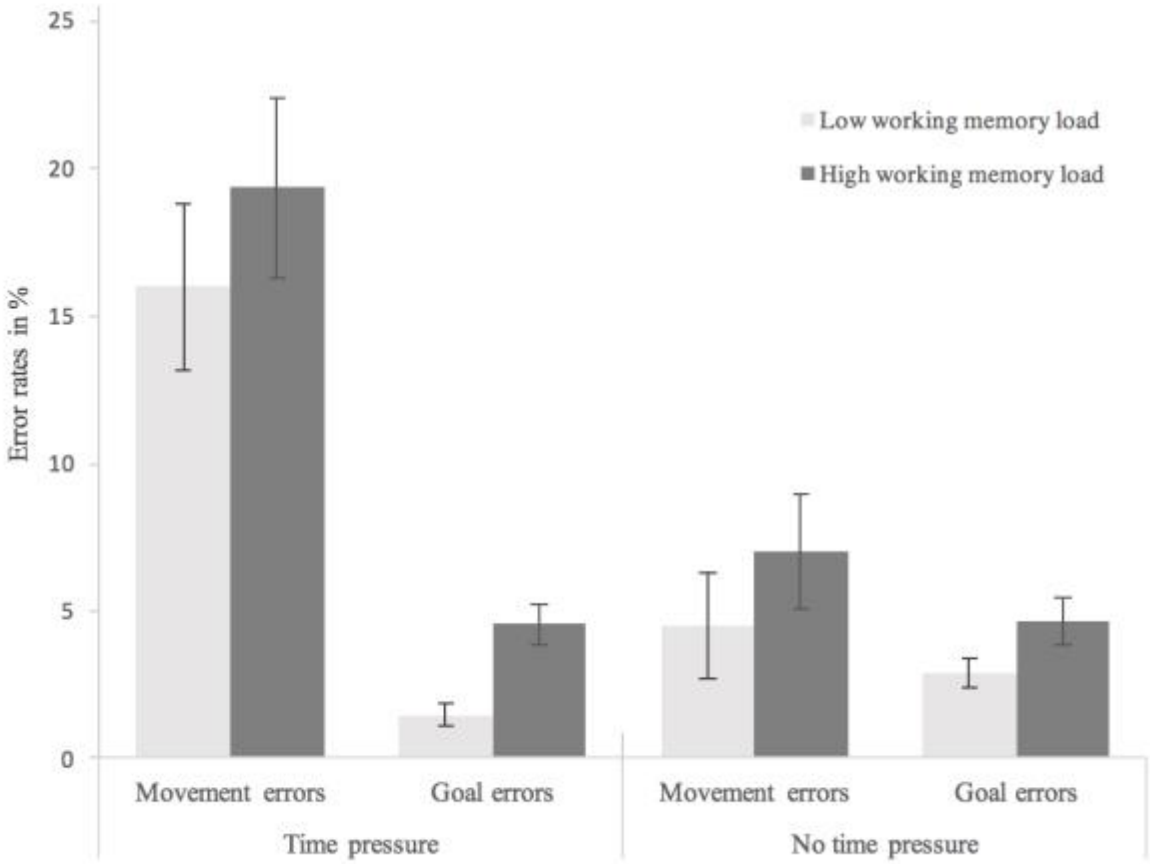

Figure 2. Movement and goal errors in relation to time pressure and working memory load. Error bars represent standard errors of the mean.

Discussion

The present research was designed to explore top-down influences on imitative behaviour. With goal focus and psychological distance considered factors that influence the degree to which individuals engage in emulation or more literal imitation (Hansen et al., 2016), this paper aimed to investigate whether cognitive load functions as a further factor moderating this relationship. For this purpose, two different cognitive capacity restrictions, working memory load as well as time pressure, were employed to test their effects on movement- and goal-directed imitation separately.

The findings demonstrate that both, memory load and time pressure, affect imitation. Both memory load and time pressure disturbed overall performance which was reflected in increased error rates. However, only time pressure, but not working memory load, influenced the two error types differently. Time pressure led to elevated movement errors, whereas goal errors remained unaffected, indicating that individuals who find themselves in a stressful situation are able to maintain goal-based imitation but struggle with movement-based imitation. For that reason, time pressure has been found to facilitate emulation over more literal imitation.

Possible explanations on why different types of capacity limitations have disparate effects on imitative behaviour will be addressed hereafter with regards to recent models in cognitive psychology. The results have important theoretical implication for both imitation- as well as working memory literature.

The findings of the present study confirm the predictions made; high cognitive load causes individuals to commit more movement- than goal mistakes, whereas under low load, resources are sufficient to treat both aspects accordingly. Interestingly, however, the predictions were only confirmed for time pressure but not for memory load. Individuals who find themselves in a time-poor situation tend to neglect movements first and preferentially focus on the goal when confronted with a complex work load that exceeds their cognitive capacities. The results are in line with the theory of GOADI (Wohlschläger et al., 2003) which states that ends (goals) are more important than means (movements). According to the theory of GOADI, the observed aspects of the imitative act are ordered hierarchically, with the amount of selectable goal aspects dependent on cognitive capacities. If there is enough capacity or attentional resources for all components that are sought to be completed, all components will receive the attention they require and can be treated with the same level of care, as was the case for low time pressure in the present study. However, if resources are limited, the theory states that movements will be neglected before goals, which was in fact the case for the high time pressure condition.

Furthermore, the goal-minimum-error pattern of the pen-and-cup task (least mistakes were committed on the goal aspect; cup < effector < grip) was taken as support for goal-directed imitation and used to create the GOADI theory. Under high time pressure, the error-pattern of the original pen-and-cup task was replicated. However, only when the variable time-load was removed from the experimental design did it become apparent that it may have been time pressure all along that caused the movement mistakes to be elevated compared to goal mistakes. This opens up room for debate as to whether the error pattern seen in the original pen-and-cup task may also have entirely or partly occurred due to time pressure? To our knowledge, participants performing the pen-and-cup task were always instructed to imitate as fast as possible. The task has also been previously referred to as speeded-response procedure (Heyes & Bird, 2008). Therefore, I suggest that further studies should try to replicate the experiment, but change the task's nature from a speeded version to a self-paced one, instructing the respondents to take as much time as they need in order to imitate the presented actions most precisely. I propose that in the case of a self-paced experiment, movements will be imitated with similar accuracy as goals, which means emulation will no longer dominate over more literal imitation.

Importantly, time pressure did not affect the accuracy of reproducing the goal aspect. The findings propose that time pressure may decrease perceptual, but not inevitably intentional induction. Time pressure did not impact the focus on the goal of the model’s behaviour, however, it decreased the focus on movement kinematics. That is, under time pressure, individuals engage more strongly in emulation, meaning they devise their own means to achieve the same end state. Those findings are in line with those found by Hansen et al. (2016). One explanation may be that they unconsciously choose the most efficient movements to attain the goal when struggling for time, as was the case in the imitation study conducted by Bekkering et al. (2000) where participants preferred to use their ipsilateral hand, and therefore chose the fastest way, to reach one of two dots on the table even when the model used contralateral movements. This might be a coping strategy to save time and use limited resources most efficiently.

An open question, however, is why working memory load did not affect imitative behaviour in the hypothesised way, that is, increasing movement mistakes relative to goal mistakes. One explanation may be that the load imposed was not sufficient in size to obtain the same effects as observed under high time pressure. Another explanation may be provided by looking at working memory models themselves. Models of working memory, such as the multi-component model, make a clear distinction between passive maintenance, on the one hand, and a system dedicated to active manipulation, in the form of executive control, on the other (Repovš & Baddeley, 2006). Due to the nature of the N-back task used in the presented experiment, it may have been that the task primarily loaded on the passive system of the working memory and therefore did not interfere severely enough with the active system to disrupt complex cognitive functions that require central executive processing, such as imitation. It has repeatedly been suggested (Bunting, Cowan, & Scott Saults, 2006; van Leeuwen et al., 2009) that rehearsal may be used as the coping strategy of choice for the N-back task. Articulatory rehearsal is a process analogous to sub-vocal speech (Repovš & Baddeley, 2006), which allows participants to keep memorised information from fading by repeating the information in their mind over and over again until needed. Articulatory rehearsal is processed in the phonological loop, which is part of the passive system of the working memory (A. Baddeley, 1992; Repovš & Baddeley, 2006). Time pressure, on the other hand, imposed broader restrictions on the working memory and, besides other functions, impacted the active system. Whenever the active system is disrupted, various complex cognitive tasks that require focused attention, like imitation, are impaired (Repovš & Baddeley, 2006).

According to the time-based resource-sharing model (Barrouillet, Gavens, Vergauwe, Gaillard, & Camos, 2009), which explains the relationship between time and cognitive load, elementary processes like manipulation and maintenance can only take place one at a time as both rely on a single limited attentional resource. Maintenance can take place for 1 to 2 seconds without needing any attention, even without sub-vocal speech (A. Baddeley, 1992). Therefore, as the imitation part in the present experiment consumed less than two seconds, the active system would not have been severely impacted during the maintenance of the numbers and was free to control behaviour during the imitation task. This explanation is supported by a study conducted by Robbins et al. (1996) in which a random digit generation task, which loads on the active system, disrupted chess playing, a complex cognitive task, whereas articulatory suppression, which loads on the passive system, did not. The present results show the exact same pattern and therefore add evidence to working memory literature.

We propose that all tasks that disrupt the active system should lead to the same error pattern as observed in the present experiment (more movement mistakes than goal mistakes under high load). To strengthen our proposal, future research would do well to apply tasks that load on the active system (e.g. the random digit generation task) and investigate whether a similar error pattern, as observed in the time pressure condition, of imitative responses occurs. The same should be done with tasks that load on the passive system to see whether a non-modulating effect occurs repetitively.

A few limitations of this study should be mentioned. Firstly, there is a possibility that participants realised that feedback was only given on the key presses, not on the key releases, however. This may have influenced their behaviour by amplifying their focus on the key presses and in turn led them to neglect movements. Secondly, Hansen et al. (2016) found that task motivation increased the exactness of imitation, therefore task motivation may display a confounding variable that has not been controlled for in our study. However, the researchers still found significant results after controlling for this variable. Both of these limitations could easily be prevented by having participants fill out a short questionnaire after task completion, assessing both face validity and task motivation.

It should also be mentioned that findings may have been confounded by demographic features. The majority of participants were female, rather young (18-30) and university students. Cognitive capacities vary between male and female as well as between young and old (Stern et al., 2005) and also depend strongly on educational level due to better cognitive training (Van Hooren et al., 2007). It would have been interesting to analyse cognitive capacities beforehand and evaluate them against imitative results.

Besides theoretical implications for imitation and working memory literature, the findings of the present study have practical implications for learning in both educational and work settings, as well as for motivation. For example, it can be frustrating when repeated approaches do not lead to the expected outcome. If, in any given action, goal attainment appears to not be an easily achievable task, it may be helpful to focus on the underlying movements first. The copying of movements provides a more direct feedback of efficacy in task execution and can, therefore, increase feelings of self-efficacy and goal progress, which in turn fuels internal motivation, consequently resulting in faster and more efficient learning. Directing the focus on movements may also be useful in situations where models are introduced to achieve behavioural change, e.g. to provoke sustainable or prosocial behaviour. Furthermore, it is important to note that in stressful situations where movement errors are promoted, productivity or results may be compromised. Additionally, in situations where adherence to a certain procedure is of importance, e.g. in learning a new technique in sports or learning how to perform surgery in medicine, it is advisable to reduce time pressure to a minimum in order to promote focus on individual movements. Conversely, applying time pressure might be useful in situations where individuality and diversity are encouraged.

Conclusion

In conclusion, imitation seems to occur on a continuum influenced by top-down modulations. The evidence gathered in this research does not indicate a correlation between working memory load and a modulation of imitative responses. Time pressure, however, modulates the relationship between high-level emulation and more literal imitation by shifting the focus towards the action goal. By increasing time pressure, the application of specific movements may decrease, facilitating more flexible high-level emulation, where goal focus is maintained but may be achieved by devising alternative means.

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Figure list

Abbreviations

GOADI-Theory…………………………………………………Theory of Goal Directed Action

Appendices

Appendix A

Abstract

Imitation is a complex perceptual-motor coordination that, as a type of social learning, plays a crucial role in skill acquisition. Despite the functional significance, its underlying mechanisms are yet to be fully discovered. The present research aimed at investigating whether cognitive load acts as a factor that moderates the degree to which individuals engage in more literal imitation versus high-level emulation. In a mixed-design study, 57 participants performed an adapted version of the pen-and-cup task (Wohlschläger et al., 2003), whilst being exposed to two different load conditions. Working memory load introduced specific cognitive limitations, whereas time pressure introduced more general limitations on different levels, including perceptual, motor and cognitive functions. Hand- and goal mistakes were measured independently and served as dependent variables. Both time pressure and working memory load affected imitation by increasing error rates in general. However, only time pressure, but not memory load increased movement-errors relative to goal-errors. Therefore, under high time pressure individuals focus more on the goal and devise their own means for the achievement, consequently showing less literal imitation. Theoretical and practical implications are discussed.

Keywords: imitation, emulation, working memory, cognitive load, time pressure, stress

Zusammenfassung

Imitation beschreibt eine komplexe Koordination zwischen Wahrnehmung und Motorik, welche als eine Art des sozialen Lernens eine entscheidende Rolle im Erwerb neuer Fähigkeiten spielt. Trotz der funktionellen Bedeutung, sind die zugrundeliegenden Mechanismen noch nicht vollständig erforscht. Die vorliegende Untersuchung soll prüfen ob kognitive Belastung einen Faktor darstellt welcher das Wechselspiel zwischen präziser Imitation und hochgradiger Emulation moderiert. In einer Mixed-Design Studie bearbeiteten 57 Teilnehmer eine abgeänderte Version des sogenannten Pen-and-Cup-tasks (Wohlschläger et al., 2003) während sie zwei verschiedenen Lastbedingungen ausgesetzt waren. Eine Auslastung des Arbeitsgedächtnisses führte zu spezifischen kognitiven Einschränkungen, während Zeitdruck zu allgemeineren Einschränkungen auf multiplen Ebenen führte; nämlich perzeptuelle, motorische und kognitive Funktionen. Hand- und Zielfehler wurden unabhängig voneinander gemessen und dienten als abhängige Variable. Belastung des Arbeitsspeichers, als auch Zeitdruck beeinflussten Imitation indem sie Fehlerraten generell erhöhten. Allerdings nur Zeitdruck, nicht aber die Arbeitsspeicherauslastung erhöhte Bewegungsfehler relativ zu Zielfehlern. Demzufolge ist zu schließen, dass sich Individuen unter Zeitdruck mehr auf das der Bewegung zugrundeliegende Ziel konzentrieren und ihre eigenen Bewegungen konzipieren um dieses zu erreichen. Folglich zeigen diese eine weniger bewegungsorientierte Form der Imitation. Theoretische und praktische Implikationen werden diskutiert.

Keywords: Imitation, Emulation, Arbeitsgedächtnis, Arbeitslast, Stress, Zeitdruck

Appendix B

E-Prime Instructions

Greeting --

Welcome to your experiment!

Your experiment consists of a memory task and an imitation task.

To continue press:

ENTER

Training block 1 (starting with low memory load condition) ----------------------------------

MEMORY TASK

First, you will be shown a one-digit number. You need to remember this number!

Then, you will be asked to type in the number.

To continue, press the ‘SPACE BAR’.

Training block 2 --

IMITATION TASK

Within the imitation task, you have to press and hold down the ‘c’ and ‘m’ key with both your index fingers.

You will then see a model pressing the ‘red’ or ‘black’ key with one of her index fingers.

As soon as you see the key press of the model, you have to imitate the model as fast as possible.

You will get feedback on your performance.

The goal of the task is to get as many 'Correct!' responses as possible!!

To continue press 'SPACE BAR'.

Training block 3 --

IMITATION AND MEMORY TASK COMBINED

Now the memory task and the imitation task will be combined.

First, you have to press and hold 'c' and 'm'.

Secondly, a number will be presented on the screen. You have to remember it.

Thirdly, you will see the model pressing a key. You then have to imitate it.

Fourthly, after imitating you need to type in the number you memorized.

To continue to your test trial press 'SPACE BAR'.

First experimental block --

Did the procedure become clear to you? If not, please contact the experimenter!

Now, the actual experiment starts!

Be prepared! The key presses of the model will now be presented faster!

!! REMEMBER: THE GOAL IS TO GET AS MANY AS POSSIBLE 'Correct!' RESPONSES !!

To start the trial, press the 'SPACE BAR'.

Training block 4 (high memory load) ---

Now, you will perform another memory task.

Instead of recalling the very last number presented, you now have to recall the second last number.

For example, if you see the sequence of the numbers
4, 7, 3, 2, the correct number to be recalled is 3.

In what follows, you will exercise this memory task without doing the imitation task.

To continue press the 'SPACE BAR'.

Training block 5 ---

Now the newly learned MEMORY TASK and the IMITATION TASK will be combined.

First, you have to press and hold 'c' and 'm'.

Secondly, a number will be presented. Try to remember it.

Thirdly, you will see the model pressing a key. You then have to imitate it.

Fourthly, after imitating you need to type in the number you memorized.

To start your test trial press 'SPACE BAR'.

Experimental block 2 ---

Now, the actual experiment starts!

Be prepared! The key presses of the model will now be presented faster!

!! REMEMBER: THE GOAL IS TO GET AS MANY AS POSSIBLE 'Correct!' RESPONSES !!

To start the trial, press the 'SPACE BAR'.

Additional short training block 6 ---

Now, you have to do the FIRST combination of the memory and imitation task again. That is, you need to remember the LAST presented number and then imitate the key press.

You can again practice the following task for a few times, before you start the actual experimental session.

To start your test trial press 'SPACE BAR'.

Experimental block 3 ---

Now, the actual experiment starts!

Be prepared! The key presses of the model will now be presented faster!

!! REMEMBER: THE GOAL OF THE TASK IS TO GET AS MANY AS POSSIBLE 'Correct!' RESPONSES !!

To start your trial, press the 'SPACE BAR".

Additional short training block 7 ---

Now, you have to do the SECOND combination of the memory and imitation task again.

That is, you need to remember the SECOND LAST number presented and then imitate the key press.

You can again practice the following task for a few times, before you start the actual experimental session.

To start your test trial press 'SPACE BAR'.

Experimental block 4 ---

Now, the actual experiment starts!

Be prepared! The key presses of the model will now be presented faster!

!! REMEMBER: THE GOAL OF THE TASK IS TO GET AS MANY AS POSSIBLE 'Correct!' RESPONSES !!

To start your trial, press the 'SPACE BAR".

!! REMEMBER: THE GOAL OF THE TASK IS TO GET AS MANY AS POSSIBLE 'Correct!' RESPONSES !!

To start your trial, press the 'SPACE BAR'.

---------------------------------- if starting with high memory load ----------------------------------

MEMORY TASK

Now, you will have to perform a memory task.

First, you will see a one-digit number. You have to remember this number.

Then, you are asked to recall this number.

Afterwards, you will see the next number.

From now on, you need to recall the SECOND LAST number.

For example, if you see the numbers

4, 7, 3, 2, the correct number to be recalled would be 3.

To continue, press the 'SPACE BAR'.

Appendix C

Informed consent as provided by the University of Ghent (Flemish)

UNIVERSITEIT GENT

FACULTEIT **PSYCHOLOGIE EN PEDAGOGISCHE WETENSCHAPPEN**

Vakgroep **Experimentele Psychologie**

INFORMED CONSENT VRIJWILLIGERS

Ik ondergetekende, ..., verklaar hierbij dat ik, als proefpersoon bij een experiment aan de Vakgroep Experimentele Psychologie van de Universiteit Gent,

(1) de uitleg over de aard van de vragen, taken, opdrachten en stimuli die tijdens dit onderzoek zullen worden aangeboden heb gelezen en dat me de mogelijkheid werd geboden om bijkomende informatie te verkrijgen.

(2) totaal uit vrije wil deelneem aan het wetenschappelijk onderzoek.

(3) de toestemming geef aan de proefleider om mijn resultaten op anonieme wijze te bewaren, te verwerken en te rapporteren.

(4) op de hoogte ben van de mogelijkheid om mijn deelname aan het onderzoek op ieder moment stop te zetten. Indien ik deelneem in het raam van mijn opleiding heeft het stopzetten van mijn deelname geen negatieve invloed op mijn punten (er worden geen punten afgetrokken, maar ook niet verdiend).

(5) ervan op de hoogte ben dat ik op aanvraag een samenvatting van de onderzoeksbevindingen kan krijgen.

Gelezen en goedgekeurd op ………………………. (datum),

De proefpersoon

Faculteit Psychologie en Pedagogische Wetenschappen – Vakgroep Experimentele Psychologie
Henri Dunantlaan 2, B-9000 Gent www.UGent.be

Appendix D

Imitation pictures

Figure 3D. Starting position of the imitation task.

Figure 4D. Left hand movement to target key "T" in the imitation task.

Figure 5D. *Left hand movement to target key "U" in the imitation task.*

Figure 6D. *Right hand movement to target key "U" in the imitation task.*

Figure 7D. Right hand movement to target key "T" in the imitation task.

Appendix D

Curriculum Vitae: Sonja Syslo, BSc

Personal Details

Name	Sonja
Surname	Syslo
Date of Birth	22.01.1992
Contact	sonja.syslo@gmail.com

Education

2002 – 2006	High school Klosterneuburg (science-based)
2006 – 2011	Commercial High School Tulln (Handelsakademie)
2011 – 2015	University of Vienna – Bachelor Psychology
Jul. – Nov. 2013	University of Western Australia – Non-EU student exchange
2015 – Jan. 2017	University of Vienna – Master Neuropsychology
Oct. – Dec. 2015	University of Ghent – Research internship
Mar. – Jun. 2016	University of Western Australia – Non-EU student exchange

Work Experience

AUVA - Austrian Workers' Compensation Board Internship	August 2008
Unfallchirurgiezentrum Valentin (trauma surgery center – private practice) Marginally employed	Jun. 2012 - Jun. 2013
Schottenhof (animal-assisted pedagogy and therapy) Volunteer work	April, May, June 2015
University of Ghent (Belgium) Research internship	Oct. – Dec. 2015
Bread in Common (Australia) Marginally employed	Aug. – Sep. 2016

Additional Skills

Languages	German (mother tongue), English (fluent in speaking and writing) – Dec. 2015: C2 – CEFR (Common European Framework of Reference for Languages), Italian (basic)
IT skills	Microsoft Office, Prezi (interactive presentations) SPSS (advanced), R (basic), SPM-8 (fMRI), E-Prime (programming)
Broadenings	Human Neuroanatomy (University of Western Australia, Perth) PS Advanced MR neuroimaging: Functional Magnetic Resonance Imaging and Susceptibility-Weighted Imaging of the Human Brain (Medical University of Vienna)

Interests

Neuropsychology, Neuroscience, Research, Sports, Travels, Cooking & Patisserie, Ceramics

References

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