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Extraversion and Cognitive Performance on Working Memory Tasks

Does Speed Matter?

Erla Kolfinna Bjarnadóttir og Harpa Óskarsdóttir

Sálfræðideild
Hug- og félagsvísindasvið
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Peter Shepherdson

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Útdráttur

Fyrri rannsóknir sem skoða áhrif úthverfu á frammistöðu á prófum á vinnsluminni hafa gefið misvísandi upplýsingar um hvort samband sé þar til staðar. Rannsóknir hafa bent til þess að einstaklingar sem skora hátt á mælingum á úthverfu eru nákvæmari og með hraðari viðbraðgstíma við ákveðin verkefni en þeir sem skora lægra á úthverfu. Hinsvegar hafa aðrar rannsóknir bent til ekkert sambands milli þessara tveggja breyta. Til þess að öðlast betri skilning á sambandinu milli úthverfu og frammistöðu á vinnsluminnisprófum framkvæmdum við fjögur mismunandi vinnsluminnisverkefni til að kanna áhrif úthverfu á hugræna frammistöðu. Þessi vinnsluminnisverkefni eiga það sameiginlegt að fundist hefur samband milli þeirra og úthverfu. Þessi verkefni eru: breytingagreining (e. *change detection task*), Brown-Peterson verkefni, flókið minnisgrip (e. *complex span task*) og Sternberg verkefni. Markmið þessarar rannsóknar var að athuga hvort úthverfa hefði jákvæð áhrif á hugræna frammistöðu þátttakenda á vinnsluminnisverkefnum. Þátttakendur svöruðu hluta NEO-PI-R sem mælir úthverfu áður en þeir byrjuðu á verkefnunum. Breytingagreining og Sternberg verkefnið kröfðust hraðrar og sjálfvirkar úrvinnslu en Brown-Peterson verkefnið og flókið minnisgrip kröfðust frekar ítarlegri úrvinnslu. Tilgáta okkar var sú að úthverfir einstaklingar myndu standa sig betur á verkefnum sem krefjast sjálfvirkar úrvinnslu (breytingagreining og Sternberg verkefni) en á verkefnum sem krefjast ítarlegri úrvinnslu (Brown-Peterson verkefni og flókið minnisgrip), líkt og niðurstöður Evan (2008) gefa til kynna. Bayesísk líkindagreining á sambandi úthverfu þátttakenda og frammistöðu á vinnsluminnisverkefnum styðja við núlltilgátu okkar og gefur til kynna að lítið sem ekkert samband er á milli úthverfu og frammistöðu á verkefnunum. Niðurstöður okkar eru ekki í samræmi við fyrri rannsóknir sem hafa áður gefið til kynna að úthverfir einstaklingar hafi betri hugræna færni á vinnsluminnisverkefnum. Við ályktum að úthverfa hafi ekki áhrif á hugræna frammistöðu á á vinnsluminnisverkefnum, og að frammistaða úthverfra einstaklinga á verkefnunum fari ekki eftir því hvort verkefnið krefjist hraðari og sjálfvirkari úrvinnslu.

Lykilhugtök: úthverfa • persónuleiki • vinnsluminni • hugræn færni

Abstract

Previous research on the effects of extraversion on cognitive performance on working memory tasks has reported contradictory results on the matter. Several studies studying extraversion's effect on cognitive performance have suggested individuals with a high level of extraversion respond more accurately and with faster response times on specific working memory tasks than those with a lower level of extraversion. Other studies, however, suggest there is no relationship between the two variables. In an attempt to clarify the relationship, we had participants complete four different working memory tasks that have been associated with extraversion in the past, to examine the effects of extraversion on cognitive performance: change detection, Brown-Peterson task, complex span task, and Sternberg task. Our goal was to investigate whether extraversion has a positive effect on participants' cognitive performance on working memory tasks. The participants answered the extraversion scale of NEO-PI-R before commencing the tasks. The change detection and the Sternberg task required participants to produce speeded responses, whereas the Brown-Peterson task and complex span task required more in-depth processing. Based on Evans' (2008) results, we hypothesised that extraverts would do better on tasks that require automatic processing (change detection and Sternberg task) than on tasks requiring more in-depth processing (the Brown-Peterson task and the complex span task). Our Bayesian analysis provided evidence supporting the null hypothesis, implying limited effects of extraversion on performance on working memory tasks. Our results contradict previous literature that suggests extraverts have better working memory skills than introverts. We conclude that extraversion does not have an effect on cognitive performance on working memory tasks, and extraverts' performance on the tasks does not depend on whether the task requires fast and automatic processing.

Keywords: extraversion • personality • working memory • cognitive performance

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Introduction

As many people as there are in the world, there are equally as many different personalities and mixes of personality traits. Personality is commonly characterised as the stable individual differences that are consistent, to some extent, over situations (Gray & Braver, 2002). The field of personality psychology has studied the differences in characteristics between people for quite some time and categorised these characteristics into several domains of personality. The Five-Factor Model is the most robust classification of personality domains and has created foundations for others to build and develop new personality measures (Biesanz & West, 2004; H. Reis, 2006, as cited in Archer & Smith, 2014). The five domains assessed in the Five-Factor Model are widely used in different personality assessments (Biesanz & West, 2004). Extraversion is one of the five traits the Five-Factor Model assesses and previous research has shown extraversion to have significant effects on various phenomena, such as academic motivation and achievement (Komarraju et al., 2009), life satisfaction (Kim et al., 2017), and check-ins on Facebook (Wang, 2013). Extraversion has also been linked to better performance on some working memory tasks in certain studies (Ackerman & Heggstad, 1997; Campbell et al., 2011; Lieberman, 2000), however, this relationship is not unequivocally supported (Curtis et al., 2015; Waris et al., 2018).

In this thesis, we report the results of an experiment aimed at clarifying the effects of extraversion on performance on working memory tasks. We begin by reviewing the concept of personality traits and their categorisation and interpretation, before discussing past research on their relationship with working memory and other aspects of cognitive performance. Finally, we introduce our experiment itself.

Personality measures

For decades, efforts have been made by personality psychologists to categorise personality traits. Questions were raised regarding the structure of personality; whether the focus of personality measurements should be on traits, character, needs, or temperament, along with complications of the essence of factors and how broad the personality factors should be

(Archer & Smith, 2014). Diverse ideas were put forward regarding the number of factors in personality assessments. Cattell developed a 16 personality factor system, Eysenck presented two and three factors, and Guilford used ten factors (Archer & Smith, 2014). A well-known personality structure began to gain recognition in the 1980s after some time coordinating past ideas of personality structure. This personality assessment named the five-factor model or the Big Five is, as the name implies, composed of five dimensions including characteristics that are both normal and aberrant (Markon et al., 2005). The Big Five is suggested to be the most thorough taxonomy (H. Reis, 2006, as cited in Archer & Smith, 2014) and despite divergent personality measures appearing to be different, Biesanz and West (2004) state that different personality inventories evaluate the same underlying core constructs as the Big Five.

One dimension included in the five-factor model, as well as numerous other conceptions of personality, is *extraversion*. This domain was initially proposed in the 1920s and is thought to be an important establishment that has made its way into a variety of personality taxonomies (Jung, 1923/1971; Vaughan-Johnston et al., 2020), such as Eysenck's hierarchical model of personality and the NEO inventories. Throughout the years, extraversion has been a subject of substantial personality-related research which has been recorded through inventories, such as the NEO-PI-R (Costa & McCrae, 1992).

NEO-PI-R

The NEO personality scale was the first inventory based on the Big Five (Costa & McCrae, 1992). The inventory was established by the personality psychologists Paul Costa Jr. and Robert R. McCrae (Archer & Smith, 2014) and is considered to be a comprehensive measurement of personality traits (Jang et al., 1998). Underlying evidence from past work on personality traits led Costa and McCrae to base their NEO inventories on five personality factors; *Neuroticism* (N), *Extraversion* (E), *Openness to Experience* (O), *Agreeableness* (A), and *Conscientiousness* (C) (Archer and Smith, 2014). The NEO inventories were first established in 1978, and the latest version was presented in 2010 (Archer & Smith, 2014). When designing the NEO inventory, factor analyses were applied and traits examined. Traits that had high discriminant and convergent validity were grouped together and the five factors formed (Costa et al., 1991; McCrae & Costa, 1983). Originally, the NEO Personality Inventory was composed of 180 personality-related components, including six facets for the dimensions of Neuroticism, Extraversion, and Openness to Experience. Agreeableness and Conscientiousness

were measured using a short global measure. Subsequently, the NEO-FFI was presented, the short version of the NEO Personality Inventory (Costa & McCrae, 1989, as cited in Archer & Smith, 2014), and in 1992, the NEO-PI-R emerged. NEO-PI-R is a broadly recognized and trusted personality measure with high internal consistency within the personality factors, varying approximately from .86 to .95 (Costa & McCrae, 1992, as cited in Veselka et al., 2012; Jang et al., 1998). The results of NEO-PI-R, therefore, show to which extent one's personality scores on the five factors.

When presented in 1992, Costa and McCrae (1992) believed the NEO-PI could assist clinicians in therapeutic processes, as the inventory would help them understand their clients to an increased extent, increase their capability to find suitable treatments and to better predict therapeutic outcomes. Researchers have found links between scores on the NEO-PI-R and mental disorders, that is, there is a pattern between certain personality outcomes and some disorders. Evidence also supports the previously mentioned statement, that the inventory can assist in determining the best course of therapy for the patient and predict therapeutic outcomes (Archer & Smith, 2014). Furthermore, using personality dimensions developed from the NEO-PI-R may also help us better understand how people's personalities are organized and described.

Interpretations of the personality dimensions

Five different personality domains are commonly used to measure people's personalities. The five domains are classified by different personality traits, as will be discussed below. *Neuroticism* is a personality dimension in the NEO-PI-R measure that includes traits such as worry, insecurity, anger, feelings of embarrassment, depression, and anxiety (Barrick & Mount, 1991). The second domain, *Agreeableness*, is referred to as characterising individuals that are soft-hearted, understanding, good-natured, sympathetic, trusting, courteous, cooperative, tolerant, forgiving, kind, and warm (Barrick & Mount, 1991; Goldberg, 1990). The third domain, *Conscientiousness*, includes traits related to dependability, such as responsibility, being organized, careful, planful, and thorough (Fiske, 1949). Volitional variables describe additional traits of conscientiousness such as being hardworking, achievement-aimed, and persevering (Barrick & Mount, 1991). Researchers have found it most demanding to identify the facets of *Openness to experience* (Barrick & Mount, 1991). Individuals who are open-minded, cultured, imaginative, curious, and have sensitivity to art, will likely score high on Openness to experience (Barrick & Mount, 1991).

According to Vaughan-Johnston et al. (2020), there is a general agreement that *extraversion* is a fundamental personality factor. Extraversion and introversion are terms often used by the general public when describing individuals' personality traits (Vaughan-Johnston et al., 2020). Extraversion is associated with social factors, and individuals who score high on extraversion have an increased tendency to be talkative, outspoken, gregarious, active, sociable, assertive, and forward (Barrick & Mount, 1991; Goldberg, 1990). In contrast, individuals who score low on extraversion are interpreted as introverted, and possess traits like being quiet, inhibited, bashful, and shy (Goldberg, 1990).

As stated by Ashton et al. (2002), extraverted individuals normally like to participate in social gatherings, enjoy talking to other people, and bring life to the party. Extraverts are likely to work in leadership positions, to be happier, be fond of their work, participate in more energetic physical activity, and be collaborative (Burke et al., 2006; Fleeson et al., 2002; Hirsh & Peterson, 2009; Jensen-Campbell & Graziano, 2001; Tolea et al., 2012). Diverse life outcomes have been linked to extraversion. Extraverts tend to score higher on measurements of life satisfaction, job, and relationships (Malouff et al., 2010; Scollon & Diener, 2006) in addition to academic achievement (Paunonen & Ashton, 2001). Extraverted individuals also tend to have more friends, relative to introverts (Van der Linden et al., 2010). Interestingly, research has also shown that car accidents are more common among extraverted individuals, that extraverted men are more likely to take risks with women they have just met, and that extraverts are stronger physically than introverted individuals (Berry & Miller, 2001; Lajunen, 2001; Tolea et al., 2012).

One theory of extraversion was proposed by Hans Eysenck, an influential theorist regarding the biological basis of personality. Eysenck (1963) suggested that individuals high in extraversion have a lower degree of cortical excitation and an increased level of cortical inhibition, contrary to introverts. This means there is a difference in the baseline of cortical activity between extraverts and introverts, such that the baseline of cortical activity is higher for introverts than it is for extraverts. Taking Hebb's (1955) theory of optimal level of arousal into account, Eysenck (1967, as cited in Bullock & Gilliland, 1993) developed his theory of arousal, suggesting that extraverts need more external stimulation to reach their optimal level of arousal, therefore seeking social situations that are more arousing. Conversely, due to the already high baseline of cortical activity for introverts, they need less external stimulation to reach their optimal level of arousal and exhibit more inhibited behaviours and seek out social situations that are nonarousing (Eysenck, 1967, as cited in Bullock and Gilliland, 1993). In his

optimal arousal theory, Hebb (1955) postulated that to function at its best, an organism must be placed at its optimal level of arousal, and if it is not, it will seek behaviours to either increase or decrease its level of arousal to reach this optimal level.

Other theorists have attempted to identify relations of extraversion with other concepts. Two personality dimensions were proposed by Gray (1970) to address the approach or inhibition of behaviour. Gray (1970) suggested that the two dimensions, impulsivity and anxiety, reflected individual differences in the strength of either (a) behavioural approach system (BAS), or (b) behavioural inhibition system (BIS), respectively. According to Zelenski and Larsen's (1999) factor analysis, extraversion can be merged into a factor with BAS strength, suggesting that extraversion and BAS strength have some common attributes and a strong correlation (Campbell et al., 2011). Gray and Braver (2002) found that participants high in BAS were significantly more accurate in tasks assessing working memory than participants low in BAS. Assuming BAS and extraversion have common attributes and are strongly correlated, this raises the question of what role extraversion has on performance on working memory tasks and whether it is a meaningful one.

Working memory

Working memory is a system that actively monitors, maintains and updates information (Chavanon et al., 2007). According to Chavanon et al. (2007), working memory is important for a vast array of reasons, including learning and problem-solving. Working memory is considered to be multilayered, with each layer serving a purpose, and Baddeley (1992) suggested that working memory can be divided into three parts: the central executive, the visuospatial sketchpad, and the phonological loop. The central executive monitors the other two systems and compares their contents to external stimuli, and is thought to be located in the dorsolateral prefrontal cortex, which depends on dopamine activity for its functioning (Lieberman, 2000). According to Chavanon et al. (2007), research has suggested an overlapping foundation of extraversion and working memory functioning, in the central executive in particular. In a study conducted by Lieberman (2000), extraverts showed better working memory performance than introverts on a memory scanning task similar to the Sternberg task, and differences in the central executive between the two groups were suggested to be responsible for their improved working memory skills. This difference in working memory skills in extraverts and introverts may be associated with the reticular formation, which

influences the dorsolateral prefrontal cortex where the central executive is thought to be located (Lieberman, 2000). As well as these differences regarding the central executive in extraverts and introverts, dopamine activity seems to be a common denominator between extraversion and working memory (Smillie & Gökçen, 2010). As reported by Chavanon et al. (2007), there is an interaction between extraversion, working memory, and dopamine to determine EEG activity as well as reaction time, as extraversion modulates the antagonistic effects of dopamine on EEG working memory load responses. Smith (2012) found no significant effects of extraversion by itself on multiple working memory tasks, yet discovered a caffeine-extraversion interaction. Extraversion seems to moderate the effects of caffeine on working memory and have an effect on performance on tasks such as Running Memory Task, a task that involves the central executive. When administered caffeine, a psychostimulant that stimulates dopamine release, extraverts perform better on working memory tasks, in contrast to the poorer performance of introverts when administered caffeine (Smith, 2012). This is in line with the suggestions of differences in the central executive between extraverts and introverts (Lieberman, 2000) and of dopamine activity being a common attribute of extraversion and working memory (Smillie & Gökçen, 2010). Based on previous studies, extraverts' cognitive performance on working memory tasks seems to be, in some way, related to their high levels of extraversion.

Cognitive performance

Personality traits have repeatedly been associated with cognitive performance. Along with neuroticism, extraversion has been shown to be linked to performance on some cognitive tasks (Ackerman & Heggstad, 1997). Dispositional traits such as extraversion, which is often associated with positive affect (Costa & McCrae, 1980), are believed to influence mood states which are then thought to influence cognitive performance, and Phillips et al. (2002) suggested that being in a positive mood can have a positive effect on performance in some types of cognitive tasks, such as enhanced recall of happy memories, and creativity. However, the literature offers contradictory reports on the effects of extraversion on cognitive performance. On some working memory tasks, extraversion has been thought to have positive effects. Extraversion has been suggested to have a significant effect on accuracy and reaction time in a change detection task (Bendall et al., 2021). According to Bendall et al. (2021), there is a speed-

accuracy trade-off in individuals high in extraversion, as they show greater accuracy in a change detection task yet take longer to detect changes than those low in extraversion. According to Lieberman (2000), extraverts perform better in a Sternberg task and have faster reaction times than introverts, and performance on a complex span task is considered to be correlated with levels of extraversion (Campbell et al., 2011), resulting in an improved performance with an increased level of extraversion.

On other types of tasks, extraversion has little to no impact on cognitive performance, and in some cases the effects are detrimental. There is a consensus that extraversion has little impact on numeric reasoning and is considered to be unrelated to visuospatial ability and verbal reasoning performance, as well as episodic memory (Sutin et al., 2019). Extraversion is considered to have no relationship with other reasoning tasks such as Wisconsin Card Sorting Test or tasks testing response inhibition or interference control (Johann & Karbach, in press). Extraverts have been found to have a reduced tolerance for repetitive tasks and be more easily distracted during the task (Costa et al., 1976; Gold & Arbuckle, 1990, both cited in Curtis et al., 2015), and extraversion has been suggested to have detrimental effects on tasks measuring sustained attention, as individuals high in extraversion are fairly slow to shift their focus away from positive locations (Johann & Karbach, in press). Furthermore, some systematic reviews have failed to identify a statistically significant association between extraversion and cognitive performance (see Curtis et al., 2015; Waris et al., 2018) and argue in favour of no relationship whatsoever, in contrast to other studies such as that of Lieberman (2000), who concludes that extraverts simply “have better working memory skills than introverts” (p. 484). Discrepancies across studies on the effect of extraversion on working memory skills may be explained by the differential use of tasks in previous studies, and features such as, for instance, whether they require effortful or automatic processing (Evans, 2008).

When research has shown an association between extraversion and cognitive performance, the association is fairly consistent with typical characteristics of extraversion (Stafford et al., 2010), which include creativity, sociability, and assertiveness (Barrick & Mount, 1991; Goldberg, 1990). In that context, those who score higher in assertiveness are thought to display better results on tasks that demand rapid and automatic processing. In contrast, on tasks demanding more in-depth processing and requiring greater effort, high scorers on assertiveness display poorer results (Evans, 2008). Evans’ (2008) results are in line with the postulation that more extraverted individuals may be faster in processing speed, but are less

inclined to think deeply about a task (Baker & Bichsel, 2006; Chamorro-Premuzic et al., 2006; Wolf & Ackerman, 2005).

Present study

In this study, our goal was to investigate the relationship between extraversion and cognitive performance on working memory tasks. The effects of extraversion on working memory performance have long been contested, with earlier studies providing opposing evidence on whether a positive or negative relationship exists, or whether there is none at all. Waris et al.'s (2018) systematic review and study investigated the unreliable reports of the effects of extraversion on performance on working memory tasks, and only found a significant relationship in 2 out of 25 samples (8%). However, Lieberman's (2000) study on the effects of extraversion on the Sternberg task showed that individuals high in extraversion perform better and have faster reaction times than those low in extraversion. Likewise, extraverts respond more accurately in change detection tasks, yet take longer than introverts to detect changes (Bendall et al., 2021). Extraverts are also thought to do better on a complex span task than introverts (Campbell et al., 2011). Therefore, those three tasks were applied in this study, accompanied by the Brown-Peterson task. The Brown-Peterson task, which is often used to assess short-term memory, is considered an appropriate measurement of working memory and evaluates divided attention and information processing (Mertens et al., 2006). Waris et al. (2018) suggested that in order to assess working memory, it would be best to combine different tasks that measure different aspects of working memory. Therefore, we chose these tasks to tap different aspects of working memory performance; whether it be speeded tasks that require quick decisions based on information stored in memory (the change detection and Sternberg tasks), or non-speeded tasks that require negotiating between relevant and irrelevant information, and trying to protect the relevant information in memory from interference from the irrelevant information (the complex span and Brown-Peterson tasks).

Our focus here is on participants' accuracy and response times in relation to extraversion scores. Two tasks required faster and more automatic processing (i.e., change detection and the Sternberg task), whilst the other two tasks required more in-depth processing (i.e., the complex span and Brown-Peterson tasks), as evidence suggests that extraverted individuals may be faster

in processing speed, but are less likely to think deeply about a task (Baker & Bichsel, 2006; Chamorro-Premuzic et al., 2006; Wolf & Ackerman, 2005). The four tasks were chosen because they are some of the major tasks that have previously been associated with extraversion, and they include two different types of demands (i.e., speed and accuracy vs. accuracy only) which gives an opportunity to investigate whether there are systematic relationships between extraversion and working memory performance under some circumstances but not others, or whether the inconsistent results from prior studies simply reflect minimal relationships combined with random noise.

Our research question is therefore as follows: “how is extraversion related to cognitive performance on working memory tasks, and does the relationship depend on whether the tasks require speeded processing?” Evidence based on work by Evans (2008), stating that individuals scoring high on extraversion perform better on tasks requiring fast and automatic processing, prompted us to predict that participants who score high on extraversion would provide better outcomes on the change detection task and the Sternberg task (i.e., the two speeded tasks), but not necessarily on the Brown-Peterson task and the complex span task. However, another plausible outcome would be that extraversion has a beneficial effect on participants’ accuracy and response time in the Sternberg task, and accuracy in the complex span task as well as in the change detection task, but may take longer to identify a change in the change detection task. This is based on research by Bendall et al. (2021), suggesting that individuals who score high on extraversion show greater accuracy on a change detection task, but take longer to identify changes.

1. Method

1.1. Participants

Forty participants, aged between 19 and 78 years ($M = 40.2$, $SD = 14.9$), of whom 50% identified as female ($n = 20$), were recruited from the online participant recruitment platform Prolific Academic (<https://www.prolific.co/>) and each participant received £4 compensation for their participation. Informed consent was obtained preceding the experiment and participants received a debriefing of the purpose of the study when they had completed it, as well as their compensation. In addition to the initial compensation, participants received a bonus based on

their performance, ranging from £0 to £1. The experiment was conducted in accordance with the Declaration of Helsinki and the ethical guidelines of the faculty of Psychology at the University of Akureyri, Iceland.

Participants were required to be over 18 years of age and have English as a first language. Participants were required to reside in and be citizens of Australia, Canada, Ireland, New Zealand, the United States, or the United Kingdom to guarantee fluency. Participants were required to have an approval score on Prolific greater than 98%. The majority of the participants came from the United Kingdom, 90% ($n = 36$), followed by Canada, where five per cent ($n = 2$) of the participants come from. The remaining five per cent of the participants came from Ireland and the United States.

1.2. Materials

The experiment was designed using PsychoPy (Peirce et al., 2019) and coded using the PsychoJS libraries. It was then hosted on Pavlovia (<https://pavlovia.org/>). The NEO-PI-R measure of personality was assessed to indicate the degree of the participants' extraversion. The measure is performed using a self-report questionnaire, with the whole scale containing 240 components divided equally into five parts, each measuring one factor of the five factors mentioned above. Participants answer on a 5-point Likert scale where they reveal to what extent they agree or disagree with each statement about their personality (Costa & McCrae, 1992, as cited in Veselka et al., 2012). Participants were asked to complete the extraversion section of the IPIP-NEO-120 (Johnson, 2014), while measurements of the remaining four factors were excluded as they were considered superfluous for this research. The NEO-PI-R extraversion measurement contained a total of 20 items. The following are instances of statements measuring extraversion; "*Make friends easily*", "*Am the life of the party*", and "*Don't mind being the centre of attention*" (Johnson, 2014). Participants made their responses on a five-point Likert scale, and response options varied from very inaccurate to very accurate.

1.3. Procedure

After completing the extraversion measure, four tasks were carried out in the experiment in a randomised order. In the change detection task (Luck & Vogel, 1997; Treisman & Zhang, 2006), participants were shown a blank screen for one second. Next, a fixation cross appeared on the screen for one second. The participants were subsequently presented with four coloured

squares, randomly positioned across the screen. 100 ms later, the squares disappeared, and a 900 ms retention interval ensued, and a fifth square (probe) was presented on the screen for two seconds. The participants' role was to determine whether this fifth square matched the colour of the original square presented at the same position on the screen (i.e., whether it was the same as or different from the original square). The participants were instructed to press the “y” key on their keyboard if they thought the fifth square was the same, and the “n” key if they thought it was different. 50 trials of the change detection task were implemented. After responding, a blank screen appeared for one second. Afterwards, participants then received a feedback message for one second indicating whether their response was correct or incorrect. Mismatching probes were always a match for the colour of one of the other-position squares presented in the original array.

In the complex span task (Conway et al., 2005; Daneman & Carpenter, 1980), participants faced a blank screen for 250 ms. Next, a fixation cross appeared on the screen for one second. Participants were then presented with lower-case letters at the centre of the screen, one at a time for one second each. When each letter disappeared, a simple equation appeared. Participants had to decipher if the equation was true or false, indicating it by clicking an appropriate button below the equation. The maximum time for completing each equation was three seconds. After the participants had completed the sequence of letters and equations each time, the screen went blank for 500 ms. They then had to reproduce the sequence of letters, in order, by typing them into a text response box. The task started off with short sequences and continued to become longer and more difficult. 10 trials of the complex span task were implemented, twice with each length of sequence from 1-5 letters in ascending order (i.e., two trials with 1 letter, two trials with 2 letters, two trials with 3 letters etc.).

In the Brown-Peterson task (Peterson & Peterson, 1959), participants were presented with a blank screen for one second. Then, a fixation cross appeared on the screen for one second. Next, participants were presented with a sequence of lower-case letters, presented one at a time at the centre of the screen for one second each. When the entire sequence was complete, a blank screen appeared for 250 ms. Participants were then presented with a series of five simple equations. Participants had to indicate whether each equation was true or false, by clicking an appropriate button below the equation. The maximum time for completing each equation was three seconds. After the last equation was completed, participants were shown a blank screen for 500 ms. Next, they were asked to recall the original sequences of letters in order, by typing them into a text response box. The task starts off with short sequences and continues to become

longer and more difficult. 10 trials of the Brown-Peterson task were implemented, twice with each length of sequence from 1-5 letters in ascending order (i.e., two trials with 1 letter, two trials with 2 letters, two trials with 3 letters etc.).

In the Sternberg task (Sternberg, 1966; Sternberg, 2016), participants were presented with a blank screen for one second. A fixation cross then appeared on the screen for one second. Next, participants were presented with a sequence of lower-case letters, presented one at a time in the centre of the screen for one second each. The sequence included letters varying from 1 to 5 and were repeated until all stimuli were presented for each trial. The participants were encouraged to try to remember the letters in any order they liked. Following the sequence, a short delay occurred for 2 seconds, and they were then presented with an upper-case letter (probe). The participants' role was to determine whether this final, upper-case letter was included in the lower-case letter sequence they had seen earlier. If the participants thought it was included, they had to press the “y” key on their keyboard, and if not, they had to press the “n” key. Afterwards, participants then received a feedback message for one second indicating whether their response was correct or incorrect. 50 trials of the Sternberg task were implemented.

1.4. Data Analysis

We conducted all data analyses in R 4.1.2 (R Core Team, 2022), using the packages *brms* (Bürkner, 2018) and *BayesFactor* (Morey & Rouder, 2015).

First, we assessed the relationships between participants' total extraversion scores (sum of scores on positively-coded items - sum of scores on negatively-coded items), and average measures of performance on each of the four tasks, by calculating correlation coefficients, which we then subjected to hypothesis tests using the *correlationBF* command. This calculates the Bayes factor in a comparison between a point-null hypothesis, and a two-sided alternative hypothesis (i.e., one that allows the correlation to be either positive or negative). We used the default JZS priors for these hypothesis tests. For the analysis of the Sternberg and change detection tasks, the relevant performance measures were accuracy (proportion correct) and RT (from correct responses). For the complex span and Brown-Peterson tasks, the measures were the total number of letters correctly recalled (of a possible 30), and accuracy on the distractor (i.e., equation) tasks (proportion correct).

Second, for the two tasks with binary choice response time data available, we fit a hierarchical Wiener diffusion model (Wabersich & Vanderkerckhove, 2014). This provides a 4-parameter simplification of the Ratcliff diffusion model (e.g., Ratcliff, 1978; Ratcliff & McKoon, 2008), an influential model of speeded decision-making that decomposes choice response time distributions into psychologically meaningful parameters. In particular, the diffusion model provides a psychological explanation for speed-accuracy tradeoffs, which had been identified as potentially relevant in the context of extraverts' task performance (Bendall et al., 2021). This allowed us to examine the effect of extraversion on boundary separation (i.e., how much evidence needs to be accumulated for a response), bias (i.e., the starting point of the evidence accumulation process), drift rate (i.e., the rate at which evidence is accumulated), and non-decision time (i.e., the time taken for pre- and post-decisional processes). We also included trial type (match or mismatch) as a predictor of drift rate, and random effects of participants for all four parameters. Because we expected drift rate to be diametrically opposed in match and mismatch trials (i.e., positive in match trials, negative in mismatch trials), yet wanted to allow for extraversion to accentuate the effect of trial type on drift rate (e.g., more extraverted individuals might have more positive drift rates for match trials and more negative drift rates for mismatch trials), we created a dummy extraversion variable in which the sign of a person's total extraversion score was flipped in mismatch relative to match trials (e.g., someone with a score of 5 would retain the score of 5 for match trials, but be given a score of -5 for mismatch trials). Thus, a positive effect of extraversion on drift rate would imply absolutely greater drift rate for more extraverted individuals, whereas a negative effect would imply absolutely lesser drift rate.

For drift rate, we used a Student's t (3, 0.8, 2.5) prior on the intercept (with an identity link function); for bias, we used a Logistic (0, 1) prior on the intercept (with a logit link function); and for boundary separation, we used a Normal (-0.6, 1.3) prior on the intercept (with a log link function). For all parameters, we used Normal (0, 1) priors on the regression coefficients, reflecting our uncertainty about the expected values.

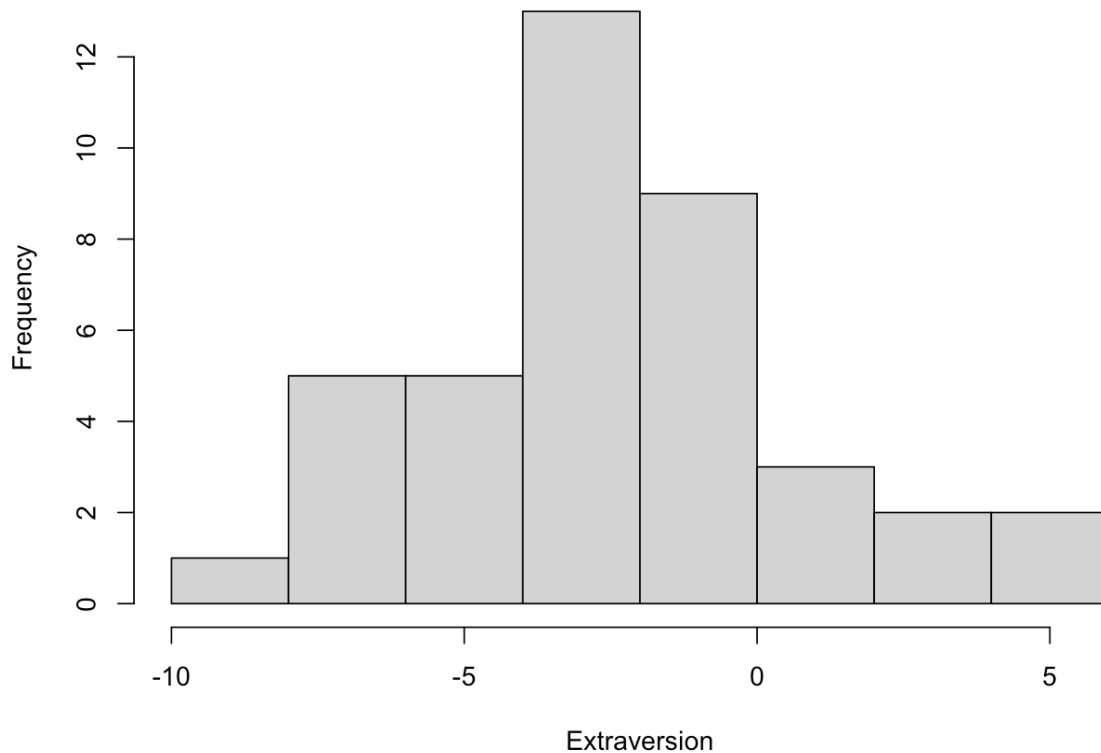
Because Bayes factors (BFs) are continuous, reflecting the relative strength of evidence for/against a hypothesis, there is no distinct cutoff to determine whether a result is "significant" or not. However, some authors have made suggestions for the qualitative interpretation of Bayes factors; here we roughly follow the recommendations of Kass and Raftery (1995), describing BF values $> \frac{1}{3}$ or < 3 as providing "weak" evidence, and values outside of that range as providing strong evidence.

2. Results

The range of possible scores available on the extraversion scale was large, with the lowest possible score being -45, indicating a low level of extraversion, and the highest possible score being 45, indicating a high level of extraversion. Scores on the extraversion scale are displayed in Figure 1. Participants' scores ranged from -10 to 5, with a mean score of -1.9. This suggests that the participants in this study were, on average, slightly introverted.

Figure 1

Scores on Extraversion Scale



2.1. Mean scores for accuracy, equation accuracy, and response time (RT)

Mean accuracy scores and response time, irrespective of extraversion level, are displayed in Table 1. Participants' mean accuracy on the change detection task was 0.8, with 1.00 being perfect accuracy. The mean response time on the change detection task was 0.91 seconds. Participants' mean accuracy on the number of letters recalled on the Brown-Peterson task was

23.43 out of 30, and equation accuracy was on average 0.91, with 1.00 being perfect accuracy. The average number of letters recalled on the complex span task was 22.9 out of 30, and mean accuracy on the equations was 0.88. Participants' response time on the Sternberg task was, on average, 0.88 seconds, and the mean accuracy was 0.96.

Table 1

Mean scores for accuracy, equation accuracy, and response time

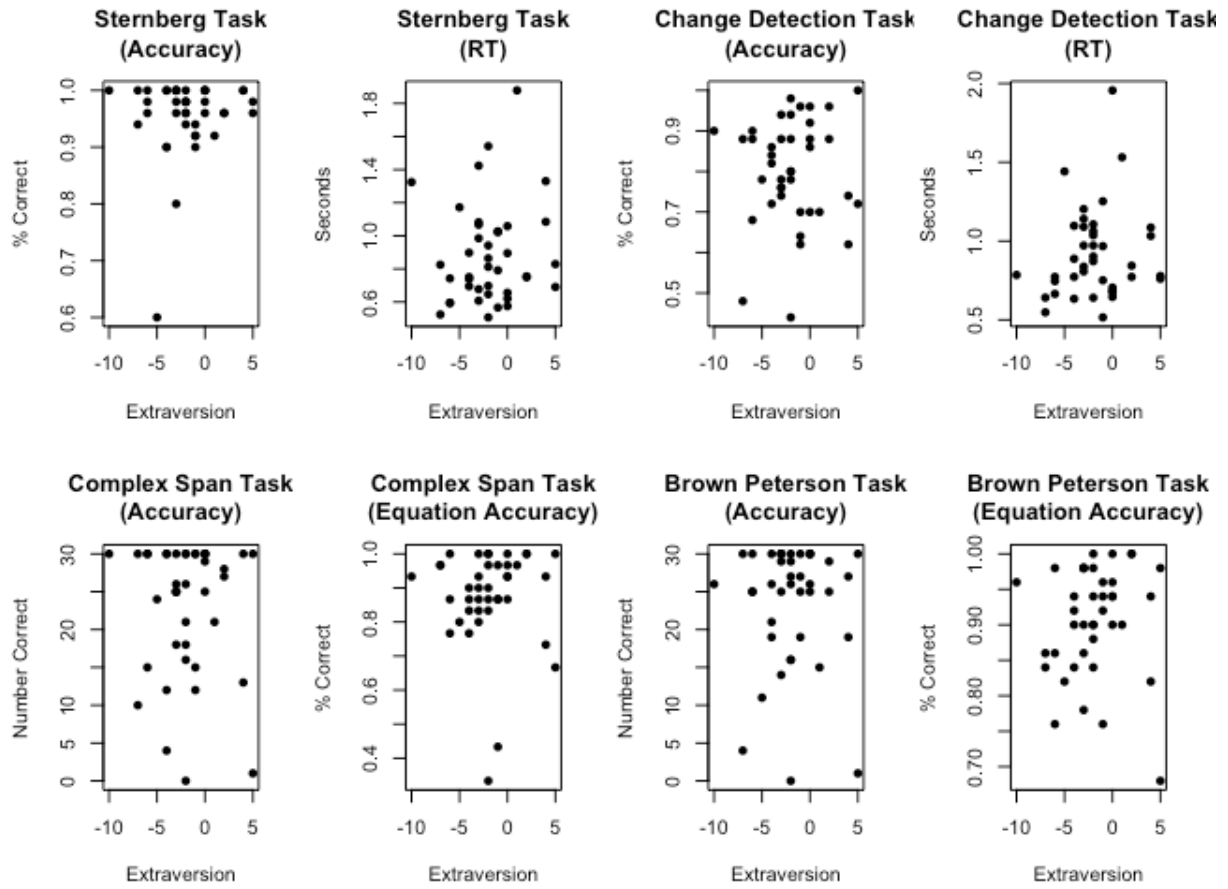
	Change detection task	Brown-Peterson task	Complex span task	Sternberg task
Accuracy	0.8	23.43	22.9	0.96
Equation accuracy		0.91	0.88	
Response time	0.91			0.88

2.2. Correlation analyses

Figure 2 demonstrates the effects of extraversion on accuracy and response time (RT) on the four tasks administered. The results suggest that extraversion has limited, if any, effect on cognitive performance on the working memory tasks, thus granting evidence supporting our null hypothesis. Results showed weak evidence against an effect of extraversion on both the accuracy of the change detection task ($BF_{10} = 0.36$), as well as response time ($BF_{10} = 0.52$). In the Brown-Peterson task, the results support evidence against an effect, both in terms of accuracy ($BF_{10} = 0.36$), and accuracy on the distractor equations ($BF_{10} = 0.37$), and thus indicate that extraversion has little effect on the Brown-Peterson task. For the complex span task, evidence was found indicating extraversion had limited, if any, effect on performance. For both accuracy ($BF_{10} = 0.38$) and accuracy on the distractor equations ($BF_{10} = 0.36$) of the complex span task, there was weak evidence against an effect of extraversion. Lastly, extraversion appears to have little, if any, effect as well on cognitive performance on the Sternberg task, according to our findings. There was weak evidence against an effect of extraversion on accuracy ($BF_{10} = 0.46$), and on response time of the Sternberg task ($BF_{10} = 0.41$).

Figure 2

Effects of extraversion on the accuracy, equation accuracy, and response time (RT)



2.3. Wiener diffusion model; effects of extraversion on parameters

We fit a hierarchical Wiener diffusion model to the data to determine whether extraversion had an effect on specific parameters for the change detection task and the Sternberg task. The model considers the effect of extraversion and trial type on drift rate, and allows bias, boundary separation, and non-decision (NDT) time to vary with extraversion. Figures 3 and 4 illustrate the effects of extraversion on the parameters on performance on the Sternberg task and the change detection. The effect of extraversion on drift rate on the change detection task was slightly negative ($v: -0.01$) and slightly positive on the Sternberg task ($v: 0.02$), indicating that extraversion had a vaguely better effect on drift rate in the Sternberg task than on the change detection task, yet did not have much effect on drift rate in either condition and would be considered ambiguous. The effect of extraversion on bias was similar for both tasks, -0.00 for the change detection task and -0.02 for the Sternberg task, implying greater extraversion was

associated with a slight bias toward the lower boundary in the Sternberg task. The effect of extraversion on boundary separation (α) for the change detection task and the Sternberg task was in both cases 0.01, indicating that more extraverted participants on the Sternberg task possibly required more evidence before making a decision. However, this difference is minuscule. The effects of extraversion on non-decision time (NDT) was 0.02 in both the change detection task and the Sternberg task. Extraversion had very little effect on the time needed to complete pre- and post-decisional processes.

Figure 3

The effects of extraversion on drift rate, boundary separation, non-decision time, and bias on performance in the Sternberg task. Error bars show 95% credible intervals, taken from the posterior.

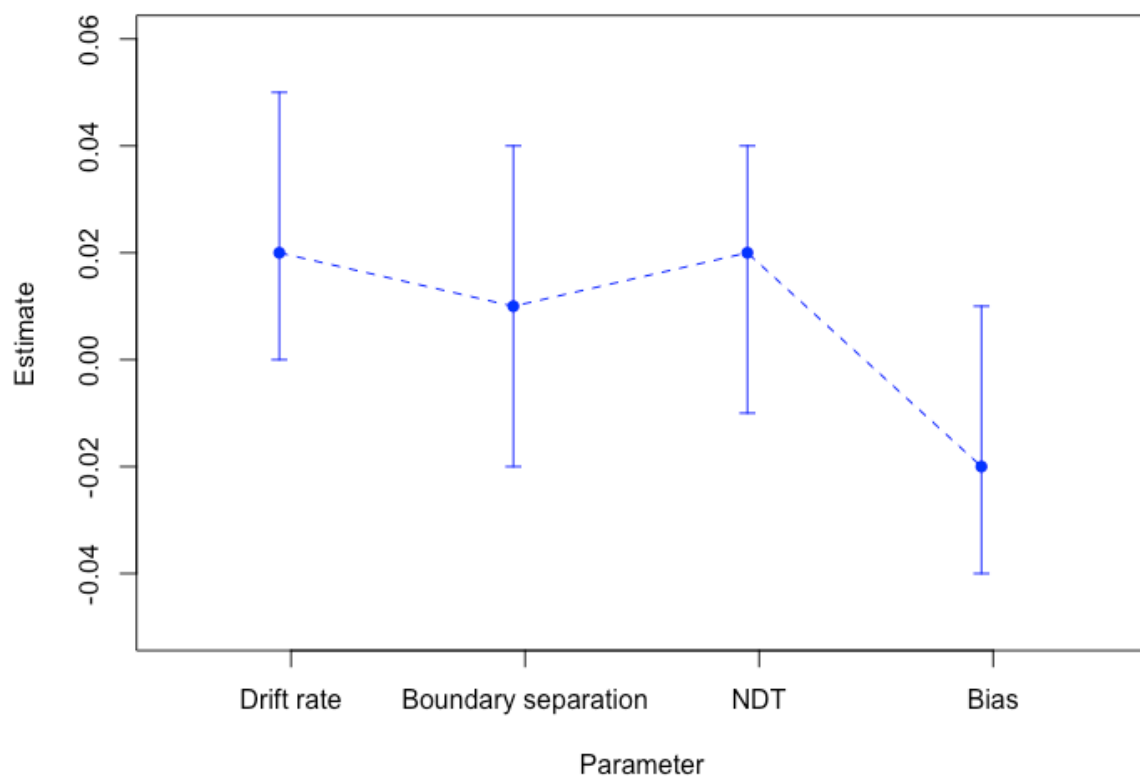
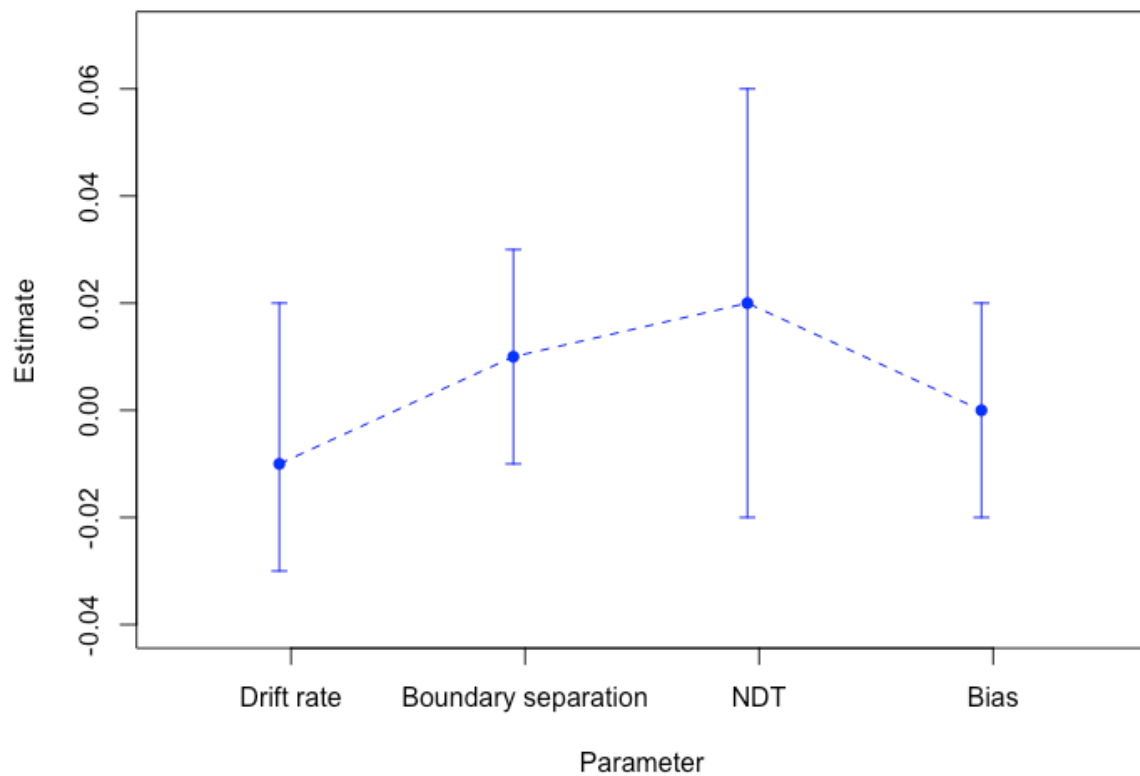


Figure 4

The effects of extraversion on drift rate, boundary separation, non-decision time, and bias on performance in the change detection task. Error bars show 95% credible intervals, taken from the posterior.



3. Discussion

The purpose of this study was to clarify the relationship between extraversion and working memory performance, given results of other studies that have found inconsistent effects. Based on previous literature on the effects of extraversion on four working memory tasks—change detection, Brown-Peterson task, complex span task, and the Sternberg task—we hypothesised that extraversion would have a positive effect on the accuracy of the complex span task, the Sternberg task, and change detection, and an effect on the response time of Sternberg task (more

extraverted people respond faster) and change detection (more extraverted people respond slower). In some research, a speed-accuracy tradeoff has been suggested to occur in the change detection task for extraverts (Bendall, 2021), meaning extraverts show greater accuracy yet take longer to detect changes than introverts. This trade-off can be evaluated in our model to determine whether extraversion has any influence on the speed or accuracy of our participants in the Sternberg task and the change detection. Our results show that extraversion was not related to performance in any of the tasks, and therefore does not produce a speed-accuracy trade-off.

Our predictions were conditional due to contradicting results in previous research: on one hand, we predicted that extraverts would perform better on tasks requiring more automatic processing, such as the change detection task and the Sternberg task, than on the Brown-Peterson task and the complex span task; on the other hand, if Bendall et al.'s (2021) statement of a speed-accuracy trade-off being present (greater accuracy for extraverts but slower to detect changes) had proven to be true, extraverts would have performed better on the Sternberg task and the complex span task, and have more accuracy but longer response time in the change detection task.

Our participants' mean level of extraversion was -1.9, meaning that on average, they fall somewhere in the middle on the extraversion scale and are only slightly introverted. This is hardly surprising given that many people are not overly extraverted or introverted. The group of people falling on the midpoint of the scale have been identified as ambiverts (Grant, 2013), a proposed third subgroup on the extraversion continuum. Whether the participants in this study would identify themselves as ambiverts remains to be known.

For tasks that required faster and automatic processing, participants were faster to respond on the Sternberg task ($M = 0.88$ sec), compared to the change detection task ($M = 0.91$ sec). Participants also had a higher mean accuracy on the Sternberg task ($M = 0.96$), meaning their answers were, on average, more correct, in comparison to answers on the change detection task ($M = 0.8$). Regarding tasks that required more in-depth processing and greater effort, results show that participants' answers were more precise on the Brown-Peterson task, compared to the complex span task. Participants recalled more letters, on average ($M = 23.43$ out of 30), in comparison to the number they recalled on the complex span task ($M = 22.9$ out of 30). Equation accuracy was higher on the Brown-Peterson task ($M = 0.91$), meaning they made fewer errors, on average, than on the equations presented during the complex span task ($M = 0.88$). Findings regarding accuracy on the four tasks do not indicate that the participants performed better on

the fast and automatic processing tasks compared to the two tasks requiring more in-depth and effortful processing.

The results of the hierarchical Wiener diffusion model for the two tasks with binary choice response options (the change detection task and Sternberg task), showed that extraversion did not have, or only had a minimal impact, on any parameter (drift rate, boundary separation, bias, or non-decision time). Extraversion did not have much of an effect on drift rate, the rate at which evidence was accumulated, though it had a slightly more positive effect for the Sternberg task. Results also showed that the drift rate coefficient on the Sternberg task was 0.02, meaning that extraversion has very limited effect on drift rate. Extraversion also had a very minimal effect on bias, the starting point of the evidence accumulation process, with participants leaning vaguely more to the lower boundary in the Sternberg task. Participants required equally as much evidence to be accumulated for a response in both of the task, though extraversion did not have a big effect on boundary separation. Lastly, consistent with previous interpreted result, extraversion did not have much of an effect on non-decision time; the time taken for pre- and post-decisional processes.

To our surprise, the results of our study show that extraversion has no effects on performance on any of the four working memory tasks, contrary to the results of multiple studies examining the influence of extraversion on the same tasks and showing a positive effect (Bendall, 2021; Campbell et al., 2011; Lieberman, 2000). On the other hand, the results of this study are in accordance with other studies that have suggested there to be no significant effects of extraversion on working memory tasks, regardless of the type of tasks (Curtis et al., 2015; Waris et al, 2018). The effects that were found in the current study were small and equally as big as the noise in the results.

According to these findings, it is fair to assume that extraversion has little to no influence on working memory performance. The question remains of how some previous literature has shown a relationship between extraversion and working memory performance, and whether the relationship is fact or fiction. That is, is the relationship, found in previous research, between extraversion and working memory performance a true relationship or merely noise in the data which has been interpreted as an effect? We suggest that it is a consequence of the latter. Our results show a limited to no relationship between level of extraversion and performance on working memory tasks, and the limited effect found is as big as the noise in the results.

3.1. Limitations

The main limitation to our study is the extraversion scores. Overall, 40 participants completed the experiment and all of them answered the extraversion part of the IPIP-NEO-120 personality measure, at the beginning of the experiment. The highest score available, suggesting a high extraversion level, was 45, and the lowest score available, suggesting a low extraversion level, was -45. The participant's extraversion scores varied from -10 to 5, specifying that no participants were very high on extraversion, or very low on extraversion. We consider the extraversion scores a limitation also due to the mean extraversion score, which was -1.9, which is slightly more in the direction of being an introvert. The lowest score of extraversion was -10 and the highest extraversion score was 5, and the majority of the participants scored either below or directly on the midpoint (i.e., 33 out of 40 participants). This indicates that most of our sample are ambiverts or more introverted, which leaves only seven participants that have scores that lean more towards extraversion. This could be considered a limitation due to a lack of diversity on the extraversion scores.

Other possible limitations to our study relates to the selections of participants and implementation of the Brown-Peterson task and the complex span task. A self-selection was utilised to gather participants in our study, where they could register to participate in the study on Prolific.com. It is unknown whether the participants have taken part in a couple of experiments, or hundreds, and if they have some knowledge on psychology experiments from experience. This could be a potential limitation due to generalisability issues to the general population, as a majority of them may not have such experience. Lastly, we were not able to conduct our experiment in a laboratory setting, therefore we carried it out online. This means that on the Brown-Peterson task and on the complex span task, we were not able to control whether the participants rehearsed the letter sequences out loud while solving the equations. In a laboratory setting, participants are typically asked to engage in concurrent articulation during the trials to prevent them from rehearsing the letter sequences prior to the memory test (Soto & Humphreys, 2008). This might be considered as a limitation to our online study.

3.2. Future directions

Future research on the effects of extraversion on cognitive performance on working memory tasks could expand to a wider range of tasks and include a bigger sample size. Future research could also pay attention to tasks we did not cover in this paper, for example, continuous

reproduction task and 2-back task. With both a bigger sample size and a wider range of tasks, potential relationships could be uncovered. If not, our aforementioned argument that prior findings showing extraversion having a favourable influence on working memory performance is in fact only a noise in the data, would receive considerably greater support.

Another possibility for future research is conducting a formal analysis of publication bias in prior literature concerning the effects of extraversion on working memory. Publication bias is a problem systematic reviews and meta-analysis occasionally deal with. If a systematic review contains a publication bias, the results are erroneous and incorrect conclusions are regarded as significant (Sutton et al., 2000). If our findings demonstrating a non-existing relationship between extraversion and cognitive performance on working memory tasks are accurate, then prior findings reflect instances where noise has been mis-interpreted as implying a relationship. Analysis of publication bias of prior findings on this topic should reveal if this is a problem in previous literature.

4. Conclusions

Despite its limitations, our study clarified the inconsistent results of previous literature, and found limited to no evidence of a relationship present between extraversion and performance on four working memory tasks. Further, the Wiener diffusion model results demonstrated that extraversion had little to no effect on the model's parameters related to the explanation for speed-accuracy tradeoffs in two binary choice-response tasks (the Sternberg task and the change detection task). Our findings therefore suggest that the relationship of extraversion on cognitive performance on working memory tasks does not depend on whether the task requires fast and automatic processing. Based on our discoveries, people who are more outgoing, talkative, and sociable (i.e., extraverted), do not necessarily perform better on working memory tasks, compared to people who are more inhibited, shy, and quiet (i.e., introverted). With an expanded sample and more diverse tasks, possible links between extraversion and performance on working memory tasks may be discovered. Alternatively, our hypothesis of no relationship between extraversion and performance on working memory tasks may be supported.

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