The role of inhibitory control and ADHD symptoms in the occurrence of involuntary thoughts about the past and future: An individual differences study

Krystian Barzykowski[1*], Sabina Hajdas[1], Rémi Radel[2†], Agnieszka Niedźwieńska[1], and Lia Kvavilashvili[3]

[1]Applied Memory Research Laboratory, Institute of Psychology, Faculty of Philosophy, Jagiellonian University, Kraków, Poland

[2] Université Côte d'Azur, Nice, France

[3] University of Hertfordshire, Hatfield, United Kingdom

† Rémi Radel passed away on 14 May 2019. He will be sorely and truly missed.

*Correspondence should be addressed to:

Krystian Barzykowski (e-mail: krystian.barzykowski@uj.edu.pl), Applied Memory Research Laboratory, Institute of Psychology, ul. Ingardena 6, 30-060 Kraków, Poland.

Acknowledgements

The present study was supported by a grant from the National Science Centre, Poland (2015/19/D/HS6/00641) to Krystian Barzykowski. In addition, the writing of the present paper was supported by the Bekker programme from the Polish National Agency for Academic Exchange (no.: PPN/BEK/2019/1/00092/DEC/1) and the National Science Centre, Poland (2019/35/B/HS6/00528) granted to Krystian Barzykowski. We thank Marcin Draszczuk for IT help in preparing the IMP. Finally, we also wish to thank two anonymous reviewers for their constructive and helpful comments on the earlier version of this manuscript.

Disclosure Statement

The authors declare no conflict of interest.

Abstract

In everyday life, people often experience involuntary thoughts about their personal past and future events in response to incidental cues in the environment. Yet, despite the abundance of such cues, our consciousness is not constantly flooded by these involuntary autobiographical memories (IAMs) and involuntary future thoughts (IFTs). The main goal of the present study was to further investigate the possibility that cognitive inhibitory control keeps these involuntary cognitions at bay. To test this inhibition hypothesis, we conducted a large-scale study (n =157) in which groups of participants with different levels of inhibitory control (low, medium, high) and individuals with ADHD spectrum symptoms were engaged in a laboratory vigilance task in which the frequency of IFTs and IAMs was assessed. Contrary to predictions, although participants across groups differed significantly in terms of their individual inhibitory control capacity, the number of IFTs and IAMs reported during the vigilance task was comparable. In addition, individuals with the ADHD spectrum symptoms did not report more spontaneous thoughts compared to other groups. Together, these findings lend little support for the idea that inhibition is a key mechanism that regulates the occurrence of IAMs and IFTs in everyday life. Other possible mechanisms and avenues for future research are discussed.

Key words: Involuntary memories · Involuntary future thoughts · Autobiographical memory · Inhibition · Cognitive control · Mental time travel · Individual differences · ADHD

1. Introduction

Every time we think about something from our personal past (e.g. *meeting with friends on Friday nights before the pandemic)* or about possible future events (e.g. *where are we going to travel once the pandemic is over*), we engage in episodic mental time travel, the ability that enables us to project ourselves both back and forward in time (Suddendorf, Addis, & Corballis, 2009). Up until recently, the main focus of research has been on deliberate forms of episodic past and future thinking, which rely on relatively slow and effortful construction and simulation of such thoughts (Wheeler, Stuss, & Tulving, 1997; D'Argembeau & Van der Linden, 2004). However, in everyday life, past and future oriented thoughts can often come to mind without any preceding attempts to think about them (e.g. Berntsen, 1996; Berntsen & Jacobsen, 2008). For example, while driving back from work, a memory of the last summer trip may simply pop into mind or we may spontaneously think of an already booked holiday adventure next summer (see Warden, Plimpton & Kvavilashvili, 2019).

Over the years, there have been two important shifts in the literature on spontaneous cognition. The first shift occurred when researchers started investigating involuntary future thoughts (IFTs) after extensively and rather exclusively investigating their retrospective counterpart (i.e., involuntary autobiographical memories, IAMs) (e.g., Berntsen, 2009; Mace, 2007, 2010). While there are still only a handful of published studies on IFTs (for a review see Berntsen, 2019), spontaneous future cognition is now considered as an emerging and fast-developing field gaining more prominence among researchers studying memory and episodic mental time travel (see Cole & Kvavilashvili, 2019a; Cole & Kvavilashvili, 2021). The second shift relates to increased realisation that rather than studying IAMs and IFTs separately, a more unified approach is needed that treats IAMs and IFTs as similar phenomena that may share important features and underlying mechanisms (Barzykowski et al., 2019a; Berntsen & Jacobsen, 2008; Cole, Staugaard, & Berntsen, 2016; Finnbogadóttir & Berntsen, 2013; Plimpton, Patel & Kvavilashvili, 2015; Vannucci, Pelagatti, & Marchetti, 2017).

The growing number of studies examining both IAMs and IFTs is mainly due to recent advances in experimental methodology that enable researchers to elicit and quantify the occurrence of spontaneous phenomena under well-controlled experimental conditions. For example, a laboratory method, developed by Schlagman and Kvavilashvili (2008; for further modifications, see Barzykowski et al., 2019b; Barzykowski & Niedźwieńska, 2016, 2018a, 2018b; Barzykowski, Niedźwieńska, & Mazzoni, 2019; Barzykowski & Staugaard, 2016, 2018; Niedźwieńska & Kvavilashvili, 2018; Plimpton, et al., 2015; Vannucci et al., 2014, 2015, 2019), examines the precise moment of the occurrence of spontaneous thoughts (e.g. Barzykowski, 2014; Barzykowski & Niedźwieńska, 2012). In this method, participants are engaged in a monotonous vigilance task while being exposed to irrelevant word phrases some of which may incidentally trigger involuntary thoughts (see Berntsen, 1998; Mace, 2004 for the role of cues in eliciting IAMs in everyday life). Importantly, participants either report any spontaneously occurring past or future oriented thoughts or, when stopped at random times, describe the nature (spontaneous vs. deliberate) and the contents of their thoughts (later classed as past or future oriented).

With this method, researchers have been able investigate a variety of theoretically important questions like for example, comparing retrieval times of involuntary and voluntary thoughts about the past and future (Cole, Staugaard, & Berntsen, 2016; Schlagman & Kvavilashvili, 2008), examining the role of triggers in eliciting involuntary thoughts (Mazzoni, Vannucci & Batool, 2014; Vannucci, Pelagatti & Marchetti, 2017), and studying the effects of long-term priming on the occurrence of IAMs (Mace & Petersen; 2020; Mace & Unlu, 2020).

1.1. The cognitive inhibition dependency hypothesis of involuntary past and future thinking

Another recent line of research involves addressing an important theoretical question about why we are not constantly flooded by these involuntary thoughts in daily life given that both IAMs and IFTs are often triggered automatically in response to incidental external and internal cues (e.g. Barzykowski et al., 2019a; Vannucci, Pelagatti, Hanczakowski, Mazzoni, & Paccani, 2015). According to the inhibition dependency hypothesis, one possible mechanism that may reduce the chances of experiencing IAMs and IFTs in everyday life is cognitive inhibition (e.g. see Barzykowski et al., 2019a). In other words, we may not be inundated by past and future oriented thoughts while carrying out daily activities (e.g. when reading or writing this paper) because a cognitive control mechanism suppresses memories and thoughts that are triggered by incidental cues and prevents them from constantly entering and interrupting our stream of consciousness with task irrelevant information.

This idea, which we call the inhibition dependency hypothesis, is not new and has been previously put forward by Conway and Pleydell-Pearce (2000) in their self-memory system model of autobiographical memory (for later modifications see Conway, 2008, 2009; Conway & Jobson, 2012) and in a broader framework of inhibitory control proposed by Hasher and colleagues (Hasher, Lustig, & Zacks, 2007; Hasher, Zacks, & May, 1999). According to the self-memory system model, autobiographical memories are constantly activated at sub-threshold level by different external and internal cues, but the vast majority of such memories do not reach consciousness because of being suppressed by constantly operating *central executive control processes* (Conway & Pleydell-Pearce (2000, p. 261).[1] The existence of such a mechanism is highly functional in that it would prevent incidentally activated memories that are inconsistent with current self-goals, from reaching awareness. Conversely, when the inhibitory control processes are not fully engaged or otherwise compromised, then some of the activated memories, especially those consistent with current self-goals, are likely to be fully retrieved by passing the awareness threshold. Therefore, according to the self-memory model,

[1] In particular, Conway and Pleydell-Pearce (2000) argued that "Control processes implement plans generated from the currently active goals of the working self, and … one of their main functions may be to inhibit constantly occurring endogenous patterns of activation in the knowledge base from entering consciousness where their usual effect would be to interrupt current processing sequences" (p. 261).

the retrieval of IAMs would depend mainly on inefficient functioning of the inhibitory control mechanism; namely, the weaker this mechanism is, the more involuntary memories will reach awareness. Similarly, Hasher et al. (1999) suggested that cognitive inhibition serves an important function (among others) such as suppressing the interference from irrelevant information (see also Friedman & Miyake, 2004). Therefore, poor inhibitory control should increase individuals’ susceptibility to irrelevant stimuli, in general, and result in increased likelihood of experiencing both IFTs and IAMs, in particular.[2]

There are only a handful of published studies addressing the role of inhibitory control in the occurrence of involuntary thoughts. For example, Kamiya (2014) observed a significant positive correlation between the number of IAMs reported during a walk around the campus and the scores on the Cognitive Failures Questionnaire (CFQ, Broadbent, Cooper, FitzGerald & Parkes, 1982). Since the CFQ is a measure of minor absent-minded slips and errors in everyday life across the domains of perception, memory and action, it may reflect the weak functioning of the inhibitory processes (Friedman & Miyake, 2004) and, hence, provide indirect support for the cognitive inhibition dependency hypothesis. Similarly, Verwoerd and Wessel (2007) observed a positive relationship between high levels of distractibility and involuntary memories. In their follow-up (experimental) studies on intrusive memories of negative film scenes, Wessel, Verwoerd and colleagues (Wessel et al., 2008; Verwoerd et al., 2011) investigated further the proposed relationship between participants’ ability to resist proactive interference in working memory and the tendency to report intrusive memories. In particular, prior to the presentation of an emotional clip, to induce highly activated and easily triggered mental intrusions, they evaluated participants’ ability to inhibit irrelevant information

---

[2] It is worth ~~to~~ highlighting that while Hasher et al.~~’s~~ argue that inhibition may operate mainly at the early stages of the process (i.e., suppressing irrelevant cues that may incidentally trigger irrelevant thoughts), Conway’s model suggests that it operates at a later stage (i.e., when the memories are already formed). While the present study cannot settle these differences, our view is that rather than being mutually exclusive, both of these processes may operate simultaneously.

from the working memory. As expected, the poorer the ability to resist the proactive interference, the more frequently intrusive memories were observed in a 1-week diary (Verwoerd et al., 2011) and the more movie-related intrusive thoughts were retrospectively reported by participants over the course of 24 hours after viewing the clip. Taken together, these initial findings appear to support the idea that cognitive control may indeed influence the frequency of involuntary thoughts.

Another interesting avenue for addressing this important theoretical question, is to study individuals with attention disorders who may experience more frequent IAMs and IFTs than what is observed in the general population. In line with this assumption, several studies have been conducted in mind-wandering research on individuals with attention deficit hyperactivity disorder (ADHD), which ~~that~~ is characterised by reduced levels of inhibitory control (Barkley, 1997). The results demonstrated the positive relationship between ADHD symptomatology and spontaneous task-unrelated thoughts (e.g. Franklin et al., 2014; Jonkman et al., 2017; Seli et al., 2015; see also Shaw & Giambra, 1993).

However, so far, there is only one experimental study that has directly investigated the role of cognitive inhibition in the frequency of experiencing IFTs and IAMs. While previous studies were either using correlational methods (e.g. Kamiya, 2014; Verwoerd & Wessel, 2007) or examined the overall frequency of spontaneous task-unrelated thoughts rather than the frequency of the IAMs and IFTs (e.g. Franklin et al., 2014; Jonkman et al., 2017; Seli et al., 2015; also; Shaw & Giambra, 1993), Barzykowski et al. (2019a) experimentally manipulated the levels of inhibitory control by using a well-established paradigm of depleting inhibitory control (Radel et al., 2015; Muraven & Baumeister, 2000; Hagger, Wood, Stiff, & Chatzisarantis, 2010), and compared the number of IFTs and IAMs reported by participants before and after the depletion manipulation. Based on the idea that inhibition relies on limited resources that cannot be continuously maintained for a long time and thus are easily depleted

(Muraven & Baumeister, 2000; Schmeichel, 2007; for a more nuanced discussion see also Radel, Gruet, & Barzykowski, 2019), participants in the depleted inhibition condition performed a 60-min high-conflict Stroop task (i.e. requiring high levels of inhibitory control) before completing a laboratory vigilance task measuring the frequency of IFTs and IAMs. The manipulation successfully impaired participants' inhibitory control before they started the vigilance task, as evidenced by decreased inhibition performance on the Simon task (Simon, 1990) (see Radel et al. 2015, for a similar result). This should have resulted in increased frequency of IFTs and IAMs if such involuntary cognitions were indeed dependent on the levels of available inhibitory control. However, the findings did not provide support for the existence of any strong role of inhibitory control in the occurrence of IAMs and IFTs.

In summary, there are very few studies that have examined the role of cognitive inhibition in the occurrence of involuntary thoughts, and conflicting findings have emerged from a few correlational studies on involuntary memories and a laboratory study by Barzykowski et al. (2019a) that experimentally manipulated participants' inhibitory control resources to observe its effects on the occurrence of IAMs and IFTs in the subsequent vigilance task. Consequently, more research is needed to systematically examine the possible relationship between cognitive control and retrieval of IAMs and IFTs using a variety of different methodological approaches and task manipulations.

1.2. The present study

The overall goal of the present study was to further test the cognitive inhibition dependency hypothesis by adopting an individual differences approach and examining the frequency of IAMs and IFTs in participants selected on the basis of their individual levels of cognitive inhibitory control capacity and participants with ADHD spectrum. The study was based on the idea that people can differ from each other in terms of their inhibitory control capacity, and this may influence the frequency of experiencing involuntary task-unrelated thoughts. There is indeed growing evidence to show that people with higher inhibitory control capacity may differ substantially from those with low levels of inhibitory control on a variety of cognitive tasks and behaviours. For example, they are less prone to increased alcohol intake (e.g. Houben & Wiers, 2009), or overeating and being overweight (e.g. Anzman & Birch, 2009; Houben, 2011; Nederkoorn et al., 2010; Pauli-Pott et al., 2010), and are more successful in resisting peer pressure that results in safer driving (e.g. Jongen et al., 2011). There is also evidence showing that individual differences in inhibitory control capacity may lead to differences not only in tasks and activities that are more cognitively oriented such as, for example, unintentional stereotyping (e.g. Payne, 2005), or bilingual spoken word processing (especially in relation to within- and cross-language competition; Abutalebi & Green, 2007; Mercier, Pivneva, & Titone, 2013), but also in impulsive and/or aggressive behaviour (e.g. Allom, Mullan, & Hagger, 2016; Hsieh & Chen, 2017; Logan, Schachar, & Tannock, 1997) and emotion regulation (e.g. Joormann, 2010, Joormann & Gotlib, 2010; Kalanthroff, Cohen, & Henik, 2013).

Importantly, to strengthen the testing of the cognitive inhibition dependency hypothesis, we included a group of adults with ADHD because impaired cognitive control and low inhibition efficiency is a key symptom of ADHD (Barkley, 1997). Their deficits in inhibitory control are well documented (e.g. Depue et al., 2010; Lansbergen et al., 2007; King et al., 2007; Miller et al., 2019; Schachar et al., 1995, 2000; Wodushek, & Neumann, 2003; Woltering et al., 2013), and therefore, the inclusion of this group may provide us the most stringent test for this hypothesis. It ~~was predicted~~ could be that individuals with ADHD spectrum would be more susceptible to experiencing IFTs and IAMs compared to non-clinical populations.

Finally, the study was motivated by recent findings of Barzykowski et al. (2019a) suggesting that inhibitory control does not actually affect the frequency of IAMs and IFTs. Indeed, their manipulation of depleting inhibitory control was successful, yet no differences were observed in the frequency of IAMs and IFTs. While highly unlikely, but as pointed out by Barzykowski et al. (2019a), it could still be argued that the manipulation to deplete cognitive inhibition resources was either insufficient or the depletion of inhibition did not last long enough to have noticeable effects on IAMs and IFTs. Thus, selecting participants with, for example, ~~significantly~~ low inhibitory control capacity may be one way to address these possible limitations. Finally, since participants in Barzykowski et al.'s study were engaged in a lengthy cognitive task aimed at depleting the inhibitory resources, they were involved in a relatively short version of the vigilance task with 400 trials and 12 probes to observe the frequency of IAMs and IFTs. This might have also led to a null effect and creates a need for a longer version of the vigilance task to reliably measure the frequency of IAMs and IFTs.

In the present study we wanted to replicate and extend the findings by Barzykowski et al. (2019a), while overcoming the above mentioned limitations. First, we asked a large pool of participants to perform online well-established inhibitory tasks to evaluate their individual differences in inhibitory control capacity. This allowed us to pre-select a pool of participants characterized by low, medium and high levels of inhibitory control capacity. In addition, we selected a separate group of participants with ADHD spectrum and measured their inhibitory control capacity. Then, we randomly selected participants from these pre-selected groups of individuals and invited them to participate in the laboratory-based study examining the frequency of IAMs and IFTs under well-controlled laboratory conditions using a standard paradigm for studying involuntary thoughts originally developed by Shlagman and Kvavilashvili (2008). We used the same but longer version of the vigilance task used by Barzykowski et al. (2019a). Briefly, in this vigilance task, participants had to detect 15 infrequent target slides with vertical lines (compared to eight in Barzykowski et al.'s study) and ignore the non-target slides with patterns of horizontal lines (785 compared to 392 in Barzykowski et al.'s study). In addition, they were exposed to short verbal phrases (800 compared to 400 in Barzykowski et al.'s study), some of which could incidentally trigger task-unrelated thoughts, including IFTs and IAMs. Throughout the vigilance task, participants were probed 18 times (compared to 12 in Barzykowski et al.'s study) at random intervals to record their thoughts at the moment they were stopped (*cf.* Plimpton et al., 2015). On completion of the vigilance task, participants were given their thought descriptions and were asked to indicate whether their thoughts referred to past memories or future events. Finally, at the end of the session, we assessed the levels of inhibitory control for a second time. This was an important part of the procedure because it allowed us (1) to evaluate participants' individual inhibitory control capacity at the time of the laboratory testing, and (2) to examine the consistency between the lab and online measures of inhibitory control. Although the correlation between these measures was positive and statistically significant (for more details see the section 3.1: Laboratory scores for inhibitory control), it was not as strong as expected and therefore, in retrospect, this aspect of our method turned out to be particularly useful in testing our hypothesis.

In summary, we selected three groups of individuals with the low, medium and high inhibitory control and compared them with a group of individuals with ADHD spectrum. As explained in the discussion (see the section on limitations), selecting the discrete groups design was motivated by the desire to maximize the chances of finding out if the effect of inhibitory control existed or not, especially in light of the null results obtained in the previous large scale experimental study by Barzykowski et al. (2019). Based on the cognitive inhibition hypothesis, we expected the highest frequency of IAMs and IFTs in the ADHD and low inhibitory control groups compared to the medium and high inhibitory control groups. Alternatively, if such involuntary cognitions are not dependent on the levels of inhibitory control, as suggested by initial findings of Barzykowski et al. (2019a), then the groups would not differ in the frequency of IFTs and IAMs.

2. Method

2.1. Design

A mixed subjects design was used. The between-subjects variable was the level of inhibitory control capacity (low, medium, high). There was also an additional comparison group of participants with ADHD symptoms. Finally, the within-subjects variable was the type of involuntary thought reported during the vigilance task (IFTs, IAMs).

2.2. Participants

The Research Ethics Committee approved the Study. Written consent for participation was obtained prior to data collection. Participants were informed that they were free to withdraw from the study at any point. The study consisted of two phases: the online pre-selection phase (i.e., the online session) and the experimental session in the laboratory (i.e., the laboratory session).

Online (pre-selection) session. A total of 697 participants were recruited to the online pre-selection session, with 485 participants successfully finishing both online inhibition tasks. Out of these, 52 participants were identified either as producing unreliable data (e.g. with less than 50 percent of correct responses in any of the inhibition tasks, and/or with mean reaction times longer than 1800 ms) or being an outlier (with 3.29 *SD* or more above or below the mean for a given variable, for example, on the interference ratio in the Flanker or Stroop tasks, which relates to 1% of the theoretical distribution assuming ~~the~~ normality). Since these participants were not able to provide us with reliable estimates of their inhibitory capacity (e.g., someone might have answered a phone-call while performing a task or done the task late in the evening or night when cognitive control may not work sufficiently, e.g., Riley et al., 2017), their data was ~~were~~ excluded from the analyses, leaving the final pool of 433 participants with valid and reliable task performance. Finally, participants were divided into the following three approximately equal sized groups, based on their scores in the online inhibitory control tasks (see results section for more details): low inhibitory control capacity (144 participants), medium inhibitory control capacity (144 participants), and high inhibitory control capacity (145 participants). Participants who were not invited into the laboratory session were eligible for a 25 PLN (ca. 7 USD) lottery, that was drawn at the completion of the research project.

Laboratory (experimental) session. A total of 120 participants (predominantly undergraduate students; 47 males, M_{age} = 24.65, *SD* = 5.22, range 19–56 years; one participant did not indicate the age) were randomly recruited to the study from the initial online pool of participants. More precisely, from each online-based inhibitory control capacity group, we randomly selected and invited 40 participants to participate in the experimental study. If an individual did not accept our invitation or was not able to participate in our study, which happened on rare occasions, then a new participant was randomly selected. Therefore, the final sample consisted of 40 participants in the low inhibitory control group (20 males, M_{age} = 24.70, *SD* = 5.91, range 20–56 years), 40 participants in the medium inhibitory control group (14 males, M_{age} = 24.48, *SD* = 4.80, range 20–50 years, one participant did not indicate the age) and 40 participants in the high inhibitory control group (13 males, M_{age} = 24.78, *SD* = 5.00, range 19–43 years, two participants did not indicate the age).

Since adult self-reports of ADHD symptoms have been shown to be both reliable and valid (Murphy & Schachar, 2000), a pool of 150 new participants filled in the Semi-structured Diagnostic Interview for ADHD in adults (DIVA-2; Kooij et al., 2010; Polish translation: Jaeschke, Brudkiewicz Bron, & Kooij, 2016; for more detail see materials section). The online recruitment was advertised as targeting individuals with either previous ADHD diagnosis, current symptoms of ADHD or being at risk for ADHD. Based on their responses, a total of 37 participants (13 males, M_{age} = 25.23, *SD* = 5.34, range 19–43 years) with four or more inattentive and hyperactive-impulsive symptoms were invited to the laboratory-based experimental session and served as an ADHD spectrum group. Importantly, as suggested by

Kooij et al. (2005), the cut-off of four or more symptoms of inattention or hyperactivity-impulsivity is appropriate and sufficient for diagnosing ADHD in adults. All individuals participating in the laboratory-based session were compensated with 50 PLN (ca. 14 USD).

To ensure that our study had sufficient power, we performed ~~the~~ an a priori power analysis ~~on~~ with G*POWER 3.1 (Faul, Erdfelder, Lang, & Buchner, 2007). Although Conway and Pleydell-Pearce's (2000) theory assumes that inhibitory control system is the main mechanism that keeps involuntary cognitions at bay and hence predicts a medium to strong effect size, we based our power calculations on the effect size ($\eta_p^2 = 0.03$) obtained by Barzykowski et al. (2019) in a 3 condition (control, depleted inhibition, intact inhibition) × 2 temporal focus (past, future) mixed ANOVA that resulted in a non-significant main effect of condition. Using this effect size ($f = .18$), a correlation of $r = -.02$ between the dependent variables obtained in that study, and assuming the minimum power of .80 with an alpha level of .05, 162 participants were necessary to find a statistically significant effect in the model. Therefore, a sample size of 157, used in the present study, allowed good power to detect small to medium size effects (.18 to .25).

2.3. Materials

2.3.1. The vigilance task

As in previous studies on involuntary past and future thoughts (e.g. Barzykowski & Staugaard, 2016, 2018; Barzykowski & Niedźwieńska, 2016, 2018a, 2018b; Barzykowski et al., 2019a; Plimpton et al., 2015; Vannucci et al. 2014, 2019), we used a fully computerized version of the vigilance task described elsewhere in more detail (e.g., Barzykowski & Niedźwieńska, 2016, pp. 5–6; also see Barzykowski & Staugaard, 2016, p. 524). The main differences between the present task and Barzykowski et al.'s (2019a) design were as follows: (1) using 800 slides instead of 400, (2) fixed presentation of incidental word cues for all participants, (3) shortening the presentation of each trial from 2.5 to 2 s., and (4) providing participants with 18 instead of 12 fixed stops with thought probes. Since we used a larger number of trials, we decreased the presentation time of each trial while keeping the mean interval between the thought probes (89 s) relatively long and comparable to the mean interval in the previous studies (81 s and 83 s in the Plimpton et al., 2015, and Barzykowski et al., 2019a studies, respectively).

The vigilance task involved detecting patterns of vertical lines (fifteen target slides) in a stream of 785 non-target slides with horizontal lines. Slides were presented for 2 s with short verbal phrases (e.g., *driving a car*) displayed in the centre of each slide. There were approximately equal numbers of neutral (N = 267; e.g. *buying a bread*), positive (N = 267; e.g. *a wonderful smile*) and negative (N = 266; e.g. *unpleasant conversation*) phrases, that constituted the final pool of 800 phrases used in previous studies (e.g., Barzykowski & Niedźwieńska, 2016; Barzykowski & Staugaard, 2016, 2018; Barzykowski et al., 2019). The program stopped automatically at 18 fixed points during the presentation with the following message appearing on the screen "*Please stop and record your concentration and thoughts now*". Participants provided a brief description of the content of their thoughts (by typing it into the computer program), indicated how much they were concentrating on the task when stopped (1 = *Not at all*; 7 = *Fully concentrating*) and if the thought occurred deliberately (they decided to think about it) or involuntarily (it simply popped into their mind). The probes, which were modelled on previous literature (Barzykowski et al., 2019a; Plimpton et al., 2015), were presented in a fixed pseudo-random order and occurred at varying intervals consisting of a minimum of 42 (about 84 s) and a maximum of 50 (about 100 s) slides. While in the present study we used slightly longer intervals between the stops, it may be argued that they were still comparable to those reported by Plimpton et al. (2015), where they varied between 52.5 and 105 s and Barzykowski et al. (2019a), where they varied between 55 and 105 s.

2.3.2. Tasks accessing individual differences in inhibitory control capacity

In order to measure and evaluate inhibitory control capacity, we used well-known tasks such as the Stroop task (MacLeod, 1991; Chuderski, Taraday, Nęcka, & Smoleń, 2012) and the Eriksen flanker task (Eriksen & Eriksen, 1974) using the Inquisit Web software (Millisecond software). They were used both in the online- and laboratory-based sessions.[3]

The Stroop-like task consisted of four colour words (red, green, blue, and yellow) in Polish, printed in one of these four colours (e.g., the word red could be printed in red, green, blue or yellow colours). Participants were instructed to judge the colour of the ink of the word as fast as possible, without paying attention to the meaning of the word, by pressing a key corresponding to the colour of the ink. Each word was displayed until response (latencies were measured from the onset of stimuli) with a 400 ms interval between trials and a 400 ms error feedback screen after each error trial. While the meaning of the word and the colour of the ink were the same in congruent trials, the meaning differed from the colour of the ink in incongruent trials. In total, there were 140 trials including 70 congruent and 70 incongruent trials. Finally, for a practice trial, we used a short 14-trial version of the Stroop task that consisted of 50% congruent and 50% incongruent trials. The main task lasted up to 10 min. To evaluate its validity, the mean RTs (across all participants except those in the ADHD group who served as a sub-clinical reference group) for congruent and incongruent trials were entered into a dependent samples *t*-test. As expected, we observed longer RTs for incongruent (M = 831.00 ms, SD = 183.28) than congruent trials (M = 740.57 ms, SD = 135.89); $t(119) = 11.70$, $p = 0.001$, Cohen's $d = 1.06$. Importantly, there was a high proportion of correct responses in

[3] There is an ongoing debate about whether a general (i.e., unitary) response inhibition ability exists as there is a general pattern of weak or non-significant correlations between tasks of inhibitory control (e.g., Hedge et al., 2020; Friedman and Miyake, 2017; Rey-Mermet et al., 2018). While we do not postulate or advocate for the idea that the inhibitory control is actually an unitary cognitive construct, in the present study we decided to use two well-known tasks which according to previous research (e.g., Friedman & Miyake, 2004; Pettigrew & Martin, 2014; Stahl et al., 2014), relate to different aspects of inhibitory control, namely, the inhibition of the prepotent response (i.e., the Stroop task) and the resistance to distracter interference (i.e., the Flanker task). By combining these two types of tasks we wanted to measure a broadly understood phenomenon of inhibitory control while including its different aspects into a composite score.

both incongruent (M = 0.96, SD = 0.04) and congruent trials (M = 0.98, SD = 0.02). Finally, the task obtained an internal consistency of 0.96, assessed via Cronbach's α and 0.91, and 0.89 measured by Spearman-Brown and Guttman split-half correlations, respectively. Therefore, we argue that the task may be considered as a reliable measure of the interference effect.

In the Eriksen flanker task (Eriksen & Eriksen, 1974), participants had to press the arrow keys with either the left or right index finger according to the direction indicated by the target arrow in the centre of the screen. This target arrow was surrounded by other arrows (flankers) that participants were instructed to ignore. In congruent trials, all targets, including flankers, indicated the same response (they were pointing in the same direction). In incongruent trials, they indicated in the opposite directions and flankers activated a wrong automatic response that had to be ignored and inhibited. In total, there were 140 trials (70 congruent and 70 incongruent). Each trial was presented for a maximum of 2700 ms (the target and distractors were presented for a maximum of 1750 ms). Before starting the main task, participants were provided with an additional 10 practice trials. The main task lasted up to 10 min. As above, we evaluated the task validity. ~~As expected,~~ we observed longer RTs for incongruent (M = 471.88 ms, SD = 68.59) than congruent trials (M = 430.95 ms, SD = 58.52); $t(119) = 19.78$, $p = 0.001$, Cohen's d = 1.82. Importantly, participants obtained high proportions of correct responses in both incongruent (M = 0.97, SD = 0.07) and congruent trials (M = 0.99, SD = 0.08). Finally, the task obtained an internal consistency of 0.98, assessed via Cronbach's α and 0.92, and 0.92 measured by Spearman-Brown and Guttman split-half correlations, respectively. Therefore, we argue that the task may be considered as a reliable measure of the interference effect.

2.3.3. The positive and negative affect schedule (PANAS; Brzozowski, 2010)

To control for possible differences between groups, we used PANAS (30 items) that measure the strength of currently experienced positive and negative emotional states. More precisely, participants have to rate on a five-point scale to what extent the given adjectives correspond with their current state. The reliability coefficients (internal consistency and stability) of the Polish version of the PANAS range from 0.73 to 0.95 (Brzozowski, 2010).

2.3.4. Semi-structured Diagnostic Interview for ADHD in adults (DIVA-2; Jaeschke, Brudkiewicz, Bron, & Kooij, 2016)

The DIVA 2.0 was originally developed by Kooij and Francken (Kooij, 2012). Based on the DSM-IV, it enables the evaluation of the 18 symptoms of ADHD, in childhood and adulthood. Previous studies proved DIVA to be a reliable tool for both assessing and diagnosing ADHD in clinical settings (Deberdt et al., 2015), in adults (e.g. Ramos-Quiroga et al., 2019; Pettersson et al. 2018), in older adults (Semeijn et al., 2015, 2013), and even in police custody (Young et al., 2013). Moreover, when comparing with the Conners' Adult ADHD Diagnostic Interview for DSM-IV (Epstein, Johnson, & Conners, 2001) the DIVA 2.0 showed 100% ~~of~~ diagnostic accuracy as well as good correlations (ranging from 0.54 to 0.72) with self-reported ADHD rating scales (see Ramos-Quiroga et al., 2019).

2.4. Procedure

2.4.1. Online (pre-selection) session

Participants were recruited to the online pre-selection session via social-media, university advertisements and flyers. They were invited to visit a project website where more detailed information about the study was provided. Participants were explicitly informed that based on their results they might be invited to the laboratory session. They were provided with the information sheet explaining that the study examined people’s ability to concentrate on monotonous and boring tasks. They were also asked to follow all the instructions and to perform tasks as well as they could. Importantly, they were asked to start the study only when they were certain that their performance would not be disrupted by noise or any other distractions. Once participants agreed to participate in the online session, they were provided with the first practice version of the Stoop task that was then followed by the main task. After completing the Stoop task, participants were provided with instructions for the Eriksen flanker task. After a brief practice task, participants completed the main Eriksen flanker task. In total, the online session lasted about 30-40 minutes.

2.4.2. Laboratory (experimental) session

We used the same procedure as in the control condition in the study by Barzykowski et al. (2019a, p. 672). Upon arrival in the laboratory, and after signing the consent form, participants first rated their current levels of physical and mental fatigue (on seven-point scales, one corresponded to not endorsing the item at all, four corresponded to medium endorsement, and seven corresponded to highly endorsing the item; with all points along the scales clearly and explicitly labelled), and were then verbally informed that the experiment examined how people concentrated on monotonous and boring tasks. The experimenter only briefly introduced participants to the procedure by providing verbal instructions about how to complete the vigilance task.

Next, participants started the computerized vigilance task, which provided them with more detailed written instructions. In particular, as in previous studies (e.g., Barzykowski & Niedźwieńska, 2016, 2018a, 2018b; Barzykowski & Staugaard, 2016, 2018; Plimpton et al., 2015; Vannucci et al., 2014, Vannucci et al., 2015), participants were instructed to identify slides with vertical lines by pressing a red button (“m” on the keyboard). In addition, they were informed that they would also see word phrases in the centre of each slide, but they were not asked to respond to them during the vigilance task. They were informed that the experimental condition, to which they had been assigned ~~to~~, involved studying their ability to concentrate on a relatively monotonous and boring task of detecting line patterns while not paying attention to the words and phrases displayed on the screen. Crucially, participants were informed that during the vigilance task they might experience different types of task-unrelated thoughts, and they were provided with examples of such thoughts, including personal goals, words, random associations, current concerns, future thoughts, plans, and memories. However, no particular emphasis was put on memories and future-oriented thoughts during the briefing. Participants were only informed that thoughts could be diverse (i.e., specific, general) and pertain either to the present, past or future. Importantly, they were assured that these thoughts could be about anything and that they could simply pop into their mind spontaneously or they could have chosen to deliberately think about them. It was explained that since the study was about people's attention and concentration, the program would occasionally stop, and they would be asked to record their concentration level and the content of their thoughts at the exact moment they were stopped. Importantly, participants were encouraged to record the content of their thoughts at the exact moment they were stopped, regardless of what it was. However, participants could refrain from reporting particularly sensitive thoughts by typing "X" as an answer, or (if possible) by providing a general description of their thoughts rather than a detailed account. Before the main vigilance task started, participants filled in the Positive and Negative Affect Schedule (PANAS; Brzozowski, 2010). Each time the program stopped, they were asked to provide a brief description of the content of their thoughts (by typing it into the program), rate their level of concentration (on a seven-point scale) and indicate if the thought occurred deliberately (they decided to think about it) or involuntarily (it simply popped into their mind).

After completing the vigilance task, participants filled in the PANAS and rated the current level of physical and mental fatigue one more time. Additional manipulation checks included asking participants to rate the extent to which they had been concentrating on the task (in general), on the verbal phrases and on the vertical lines, the importance of performing the computer task as well as they could, the difficulty of the computer task, and the extent to which the task was interesting. Finally, participants also rated the extent to which involuntary thoughts and verbal phrases were experienced as interfering with the vigilance task and how much they were suppressed (involuntary thoughts) or ignored (verbal phrases) by participants.

They were then provided ~~briefly~~ with verbal instructions describing the nature of autobiographical memory (as, for example, in Schlagman, Kliegel, Schulz, & Kvavilashvili, 2009, p. 410) and future thoughts and were informed about the second part of the study. During this part, the program provided participants with more detailed written instructions. Participants reviewed all of their thoughts recorded during the vigilance task, one at a time and in the same order as they had been recorded. Participants were instructed to decide whether each thought was an autobiographical memory, future-oriented thought, thought relating to the current situation or other type of thought by clicking the appropriately labelled button. Choosing the last two options displayed the next recorded thoughts. If participants chose one of the first two options, they were asked to describe the memory or future-oriented thought more thoroughly by typing it into the computer program. This way we obtained longer descriptions of these mental contents than during the vigilance task.

Once the task was finished, participants performed the Stroop task and the Eriksen flanker task in the same way as during the online session. This way we were able to obtain measures of individual differences in participants' inhibitory control capacity under well controlled experimental conditions.

3. Results

For all statistical analyses reported below, the level of significance was set at $p < .05$, and the effect size was measured by partial eta-squared (η_p^2). We start by reporting how participants were grouped into three groups of inhibitory control capacity and then report any group differences in the background variables (e.g., their scores on PANAS, performance on the vigilance task) before moving to the analyses directly assessing the inhibitory control and

ADHD hypotheses by examining the number of spontaneous task-unrelated thoughts overall, and then as a function of type of thought (IAMs vs. IFTs) in four groups of participants.

3.1. Manipulation checks (the inhibitory control capacity across the groups)

Online scores of inhibitory control. To examine individual differences in participants' inhibitory control capacity, we first analysed their performance on the online Stroop and the Eriksen flanker tasks. In particular, we examined the standard interference effect (i.e., the difference between mean response times of incongruent and congruent trials divided by mean response times of congruent trials), which represents the time needed to inhibit the interference when taking into account the individual processing speed, and, importantly, is considered as a reliable indicator of the efficacy of cognitive control.[4] The lower the interference (i.e., the faster the interference is resolved), the stronger one's inhibitory capacity is. First, we calculated the interference ratios separately for the Stroop task and the Eriksen flanker task. Second, we standardized these scores (i.e., z-transformed them) to make them comparable with each other. Then, the general inhibitory control capacity index for each participant was calculated as a mean of these two z-transformed interference ratios. This allowed us to divide participants into three approximately equal size groups of 144 participants with the highest level of inhibitory control (with the lowest z-transformed interference ratios; M = -.72, SD = .34, range: -.30 to -1.81), 144 participants with the medium level of inhibitory control (with medium z-transformed ratios; M = .08, SD = .14, range: -.30 to .21) and 145 participants with the lowest level of inhibitory control (with the highest z-transformed interference ratios; M = .71, SD = .40, range: .21 to 1.97).

[4] Please note that we did not use a simple incongruent and congruent time difference as it does not control for individual differences in general processing speed and speed-accuracy trade-offs (e.g., Draheim et al., 2016, 2020; Hedge et al., 2018b; but see Faust et al., 1999; Hedge et al., 2018a who showed that proportional costs, as used in the present paper, may not always control for such differences). Importantly, while some methods may perform better than others, there are still ongoing discussions in the literature whether any alternative scoring methods can control for these confounds completely (for further review, see Vandierendonck, 2021).

Laboratory scores of inhibitory control. A total of 120 participants (40 from each group) were randomly selected from the pool of 433 participants divided into three groups on the basis of their online task performance. A one-way ANOVA on the mean interference ratio for these two online tasks with the inhibitory control group (low, medium, high) as a between-subjects variable, resulted in a significant main effect with a large effect size ($F(2, 117) = 188.35$, $p < .001$, $\eta_p^2 = .77$) with the strongest and the poorest inhibitory control in the high and low conditions, respectively, and the medium inhibitory control in the medium group (all $p_s < .001$).

However, since the study examined the role of individual inhibitory control in the involuntary past and future thoughts, we wanted to make sure that groups were indeed different in terms of the cognitive inhibitory control capacity during the laboratory session when the involuntary past and future thoughts were examined. In addition, we wanted to make sure that the inhibitory control capacity was reliably measured. Therefore, we asked participants to perform the inhibitory tasks in the laboratory one more time. This allowed us to re-group participants based on their inhibitory control ratios obtained in the laboratory rather than based on their initial online-session ratios.[5] More precisely, using the laboratory-based interference ratios, we re-grouped participants and divided them into three new and equally sized groups of participants with the low, medium and high inhibitory control.

Briefly, 40 participants with the highest and with the lowest mean laboratory-based interference ratios were divided into the low and high inhibitory control capacity groups, respectively. The remaining 40 participants with ratios in the middle between strongest and

[5] There are several reasons why we decided to re-group participants based on their laboratory-based interference ratios. First, the correlation between the interference ratios obtained in the online and laboratory sessions was ~~reliable but~~ relatively small in size ($r(130) = .23$, $p = .010$). Second, analysing the online- and laboratory-based interference ratios by dependent samples *t*-test revealed that they were significantly different from each other ($t(130) = 2.68$, $p = .010$, *Cohen's d* = .27) with poorer inhibition observed in the online tasks (i.e. higher interference ratio, $M = .13$, $SD = .09$) than in the laboratory ($M = .11$, $SD = .06$). Finally, when examining differences between online-based groups on their laboratory-based interference ratios, the main effect of the group was only marginally significant ($F(2, 117) = 2.65$, $p = .075$, $\eta_p^2 = .04$). For all these reasons, re-defining groups of participants based on their laboratory performance in the inhibitory tasks was the most justified and reasonable decision especially that we wanted to make sure that groups were different in terms of their cognitive inhibitory control capacity presented during the laboratory session.

poorest inhibiting individuals constituted the medium inhibitory control capacity group. This re-grouping was based primarily on re-categorizing 21, 25 and 20 participants in the low, middle and high group, respectively. The fourth group consisted of participants with ADHD spectrum and the group selection was based on the DIVA score exclusively.

Finally, we verified the expected differences between these newly created groups in terms of their laboratory scores of inhibitory control capacity. One-way ANOVA on the mean interference ratios with the inhibitory control group (low, medium, high, ADHD spectrum) as a between-subjects variable, resulted in a significant main effect, $F(3, 151) = 30.73$, $p < .001$, $\eta_p^2 = .38$. Post hoc tests indicated that, as expected, participants in the low inhibitory control group were the slowest (all $p_s < .001$) while participants in the high inhibitory control group were the fastest to exert inhibition (all $p_s < .001$). Participants in the medium group were both better ($p = .001$) and worse ($p = .001$) compared to participants in the low and high inhibitory control groups, respectively. Importantly, participants with the ADHD spectrum were only better at inhibiting than participants in the low inhibitory control capacity group ($p = .002$) and worse compared to both medium ($p = .019$) and high inhibitory groups ($p = .001$). These results are presented in Table 1 and Figure 1. This pattern of findings suggests that participants were successfully divided into three groups with different levels of inhibitory control.

3.2. Equivalence of experimental groups before, during and after the vigilance task

To test the comparability of conditions before and after the vigilance task in terms of participants' mood ratings, the overall mean positive and negative PANAS scores were entered into two separate 4 inhibitory control group (low, medium, high, ADHD spectrum) × 2 time of testing (before vs. after the vigilance task) mixed ANOVAs with repeated measures on the last factor. The analysis on the mean positive affect scores revealed a significant main effect of time of testing, $F(1, 153) = 100.73$, $p < 0.001$, $\eta_p^2 = .40$, with scores being significantly lower after completing the vigilance task (see Table 1). While the main effect of group was not significant ($F < 1$), the group by time interaction was significant, $F(3, 153) = 3.17$, $p = 0.026$, $\eta_p^2 = .06$. Post hoc tests revealed that while the positive affect was similar across the four participant groups before the vigilance task, it was systematically dropping across groups, with the lowest difference between the first and second testing in the low inhibitory group and the highest difference in the high inhibitory group. For negative affect scores, only the main effect of time of testing was significant, $F(1, 153) = 10.73$, $p < 0.001$, $\eta_p^2 = .07$, with scores being significantly lower after completing the vigilance task. This pattern of results (also observed in previous studies, e.g. Barzykowski et al., 2019a; Barzykowski & Niedźwieńska, 2018b) suggests that performing a monotonous vigilance task reliably affected participants' mood in the negative direction.

Table 1 also shows mean ratings of various cognitive and non-cognitive variables provided by participants either before, during or after completing the vigilance task. This way we were able to test the comparability of participants across groups. A series of one-way ANOVAs on these means with the group (low, medium, high, ADHD spectrum) as a between-subjects variable, revealed that participants did not differ significantly in any of these variables (all *Fs* < 2.54). Thus, the four groups were comparable in terms of self-rated physical and psychological fatigue (before and after the task), concentration (retrospective rating) on the task, levels of perceived interest and task difficulty, motivation to perform the task well, and the extent to which participants paid attention to words and phrases on the screen, were suppressing or ignoring them, or experiencing verbal phrases or involuntary thoughts as interfering with the vigilance task.

~~Interestingly,~~ the main effect of group for the extent to which involuntary thoughts were experienced as interfering with the vigilance task and concentration on the vertical lines (retrospective rating) were close to statistical significance ($F(3, 153) = 2.53$, $p = .059$, $\eta_p^2 = .04$; $F(3, 149) = 2.54$, $p = .059$, $\eta_p^2 = .05$). The post hoc tests revealed that the participants with

ADHD spectrum rated spontaneous thoughts as the most interfering compared to all other groups (all $p_s < .042$). Participants in the low inhibitory control also reported the highest levels of concentration compared to the medium group ($p = .007$).

Finally, to control for possible differences in the time-line of the experiment, the means for the overall duration of the laboratory session were entered into a 4 (low, medium, high, ADHD group) one-way ANOVA. The groups did not significantly differ from each other in this regard ($F = 1.67$, $p = .175$).

Taken together, these results suggest that any possible differences between the groups in the frequency of involuntary past and future thoughts should not be due to group differences in the level of concentration, motivation, fatigue or the way participants interacted with the vigilance task and its stimuli.

3.3. Performance on the vigilance task

All participants successfully completed the vigilance task. The results are presented in Table 1. There were no significant differences between the groups in terms of the proportion of targets detected, main effects for response times to targets, nor levels of concentration reported online (all $Fs < 1.67$, $p_s > .176$). Importantly, as presented in Table 1, the high proportion of targets detected across groups (ranging from 0.89 to 0.95), the fast correct response times (ranging from 0.82 s to 0.77 s), and concentration ratings ~~centring~~ centered around the middle of the scale (ranging from 3.92 to 4.47 on a 7-point scale, indicating average concentration level), ~~provide strong~~ which provides support for the validity of the vigilance task meant to engage participants in a cognitively undemanding activity.

3.4. Frequency and type of recorded thoughts

Given that each participant was stopped 18 times during the vigilance task, the total number of thought probes was 720 (18 × 40) in each but the ADHD condition (where there were 666 probes: 18 × 37). On 58 occasions (9 in the low, 17 in the medium, 16 in the high, and 16 in the ADHD spectrum group), participants refrained from reporting particularly sensitive thoughts by typing “X” as an answer. In addition, on 106 occasions (23 in the low, 29 in the medium, 29 in the high, and 25 in the ADHD spectrum group), they indicated that their mind was blank at the time of being stopped. This resulted in 688, 674, 675 and 625 valid thought probes in the low, medium, high, and ADHD spectrum group, respectively.

As in previous studies that used the vigilance task (Barzykowski et al., 2019a; Plimpton et al., 2015), all recorded thoughts were independently coded by the first and second author as either task-related or task-unrelated (based on criteria proposed by Smallwood, Baracaia, Lowe, & Obonsawin, 2003; Smallwood, Obonsawin, & Reid, 2003). Out of all 2662 valid thoughts, 1665 (63%) were task-unrelated thoughts (e.g., *going with my partner to cinema*), while 104 (4%) and 893 (34%) were classed as task-related thoughts (*don't forget to push the button*) or task-related interference (*this is so boring, I am tired*), respectively, and were removed from further analysis. The agreement between the raters was high (89%), and any disagreements were solved by discussion. Second, out of 1665 task-unrelated thoughts, 270 (16%) were classed by participants as occurring deliberately rather than involuntarily. Since task-unrelated deliberate thoughts were not the primary focus of the present study (i.e., their occurrence would not depend on the inhibitory control), they were excluded from further analyses, resulting in 1395 spontaneous task-unrelated thoughts.

To examine the possible effects of individual differences in the capacity of inhibitory control on the number of involuntary task-unrelated thoughts reported during the vigilance task, the numbers of these thoughts in the low, medium, high and ADHD group were entered into a one-way ANOVA with the condition as a between-subjects variable (see Table 2). The main effect of condition was not significant ($F(3, 153) = 1.08$, $p = .361$, $\eta_p^2 = 0.02$), indicating that spontaneous task-unrelated thoughts were reported with similar frequency across the four groups. A linear regression performed on the data pooled across the four conditions also did not show a significant effect ($r = 0.046$, $t(153) = 0.57$, $p = 0.570$). Together, these results appear to suggest that the number of task-unrelated thoughts was not affected by the inhibitory control capacity.

3.5. Temporal focus of thoughts

After completing the vigilance task, participants were asked to decide whether each thought they reported was a memory of a past event, a future-oriented thought or something else. To ensure the thoughts had been categorized correctly, all the entries were also screened by the first and the second author. All entries identified by participants as memories and future-oriented thoughts were in line with the classifications made by the judges. However, some of the thoughts classified as autobiographical memories or future thoughts by the judges were not identified as such by participants.[6] Re-evaluated entries (e.g. *the first time I went to England*), only with an agreement of 100% between judges, were included in the analysis. In total, 155 entries were re-evaluated by judges ~~that~~ , which constituted 19% of entries included into the analysis

Since the main focus of the present paper was on the number of IAMs and IFTs, they were entered into a 4 inhibitory control group (low, medium, high, ADHD spectrum) × 2 temporal focus (past, future) mixed ANOVA with repeated measures on the last factor (for means see Table 2). Neither the main effects of group ($F(3, 153) = .65$, $p = .585$, $\eta_p^2 = 0.01$), nor the group by temporal focus interaction ($F(3, 153) = .18$, $p = .913$, $\eta_p^2 = 0.01$), were significant. However, the main effect of the temporal focus of thought ($F(3, 153) = 9.97$, $p = .002$, $\eta_p^2 = 0.06$) was significant with more past-oriented than future-oriented thoughts. Two linear regressions performed separately on the data pooled across the four conditions also did not show a significant effect both for the number of IAMs ($r = -0.014$, $t(153) = -0.17$, $p =$

[6] As pointed out by Barzykowski & Niedźwieńska (2018a, p. 123; also Barzykowski et al. 2019a, p. 676), due to the computerised nature of the vigilance task, the decision whether a mental content was or was not a memory was irreversible, and this could have resulted in some errors that participants committed when categorizing their thought descriptions.

0.865) and IFTs ($r = 0.027$, $t(153) = 0.33$, $p = 0.742$). Together, these results appear to suggest that the number of IAMs and IFTs was not affected by the inhibitory control capacity.

4. Discussion

To examine the possible role of cognitive inhibition on the frequency of IAMs and IFTs, we selected participants with high, medium and low inhibitory control capacity based on their performance in two well-known and widely used tasks assessing response inhibition (i.e., the Stroop and Eriksen flanker tasks). Given that low levels of inhibition constitute a characteristic symptom of ADHD (Barkley, 1997), and the results of previous studies demonstrating reduced inhibitory control in these individuals (e.g. Lansbergen et al., 2007; King et al., 2007; Wodushek, & Neumann, 2003), an additional group consisting of participants with ADHD spectrum was also included in the study. By having participants with different levels of inhibitory control we were able to examine the possibility that those with high levels of inhibitory control reported fewer IAMs and IFTs in the laboratory vigilance task, than participants with low inhibitory control capacity. Like in our previous study that examined the role of depleting inhibitory control on the number of IFTs and IAMs reported in the vigilance task (Barzykowski et al. 2019a), we made every attempt to keep the conditions comparable in terms of several other background variables (cognitive and emotional).

In line with the cognitive inhibition dependency hypothesis, we ~~predicted~~ anticipated that the stronger the participants' inhibitory control capacity, the lower the frequency of their reported IAMs and IFTs would be. We also expected individuals with ADHD spectrum to demonstrate higher frequency of IAMs and IFTs compared to non-ADHD groups of participants. However, ~~in stark contrast to this prediction,~~ the number of spontaneous task-unrelated thoughts, in general, and IFTs and IAMs, in particular, did not differ across the groups during the laboratory vigilance task although groups differed significantly from each other in terms of their inhibitory capacity. In addition, in line with previous studies (e.g. Plimpton et al., 2015), participants in all groups were consistently more likely to think about their personal past than the future. Finally, another interesting and novel finding that emerged from the study was that individuals with ADHD spectrum rated spontaneous thoughts, experienced during the task performance, as more interfering even though their performance on the vigilance task did not differ from that of the other groups. Below, we will first discuss the implications that these findings have for our understanding of the nature and underlying mechanisms of IAMs and IFTs, followed by a discussion of possible limitations and avenues for future research.

4.1. Theoretical Implications

The main goal of the present study was to examine possible factors influencing the frequency of involuntary thoughts by testing the cognitive inhibition dependency hypothesis of IAMs and IFTs. Specifically, we wanted to find out what is the putative mechanism that prevents us from being constantly flooded by involuntary thoughts about the past and future in response to external and internal triggers that are readily available in everyday situations and have been shown to be crucial in eliciting these thoughts in participants (Barzykowski et al., 2019; Berntsen, 1996; Berntsen & Jacobsen, 2008; Finnbogadóttir & Berntsen, 2013; Mace, 2004; Schlagman & Kvavilashvili, 2008; Schlagman et al. 2007).

While there may be several reasons for keeping these mental contents at bay, which are not necessarily mutually exclusive, in the present study we focused on one, in our opinion, the most obvious possibility, namely, that ~~the~~ an inhibitory control mechanism keeps suppressing these task-irrelevant thoughts, preventing them from invading the consciousness. This possibility has been proposed in the literature for some time, for example, in the influential framework of inhibitory control (e.g. Hasher, Lustig, & Zacks, 2007, 1999), on the one hand, and in the model of autobiographical memory (Conway & Pleydell-Pearce, 2000), on the other. Yet, no previous study, except the recent study by Barzykowski (2019a), has subjected this hypothesis to systematic experimental investigation (but for a study on trauma-related intrusive thoughts using a similar approach see Nixon, Roberts, Sun, & Takarangi, 2021). To the best of our knowledge, this is also the first study in which the frequency of IAMs and IFTs was examined in participants with ADHD spectrum. Moreover, while the previous study by Barzykowski et al. (2019a) used experimental manipulation to deplete inhibitory resources in participants, in the present study we applied the individual differences approach to further investigate the expected relationship between inhibitory control and IAMs and IFTs. By using the same experimental method, enabling the systematic experimental control, and by applying both the experimental (Barzykowski et al., 2019a) and individual differences approach (the present study), the basic mechanisms of IAMs and IFTs and their dependency on possible inhibition mechanism were systematically examined. Surprisingly, the findings did not provide any support for the existence of such a ubiquitous control mechanism suggesting that the frequency of IAMs and IFTs may not depend strongly on the inhibitory control (capacity), or, alternatively, the size of such effect was too small to be observed in the present ~~yet relatively well-powered~~ study.

Perhaps the most surprising finding was that we did not observe higher frequency of IAMs and IFTs in people with ADHD spectrum although previous studies on mind-wandering had shown that individuals with ADHD symptoms reported higher number of task-unrelated thoughts than non-ADHD participants (e.g. Franklin et al., 2014; Jonkman et al., 2017; Seli et al., 2015; see also Shaw & Giambra, 1993). When discussing this discrepancy between findings from research on mind-wandering and involuntary thoughts, we should highlight an important difference in the methods used to study these two phenomena (see also Plimpton et al., 2015).[7] In the laboratory studies of IAMs and IFTs, participants are exposed to a steady stream of

[7] It is worth pointing out that this is not the first time that discrepant findings emerge from studies on mind-wandering and on IAMs and IFTs. For example, while future-oriented bias in task-unrelated thoughts has been reported in mind-wandering studies (e.g., Baird et al., 2011; Stawarczyk, Majerus, Maj, Van der Linden, & D'Argembeau, 2011), laboratory studies on IAMs and IFTs, using a vigilance task with word cues as in the present study, have consistently reported more thoughts about the past than the future (e.g., Cole et al., 2016; Plimpton et al., 2015; Vannucci et al., 2017).

meaningful cue words that can incidentally trigger any involuntary thought (but also possibly mind-wandering episodes; see McVay & Kane, 2013). By contrast, in most studies of mind-wandering (e.g. Jackson, Weinstein, & Balota, 2013; Jonkman et al., 2017) participants are usually exposed to non-verbal stimuli such as digits (e.g. in the Sustained Attention to Response Task; SART; Robertson, et al., 1997). It may be argued that ADHD individuals have difficulty with maintaining focus on tasks~~;~~ used in mind-wandering studies, precisely because these tasks do not contain any meaningful (verbal) information. By contrast, having verbal phrases in studies of IAMs and IFTs may help such individuals to maintain a certain level of focus, limiting the episodes when they switch off and start mind-wandering. Another possible difference across the methods involves the ongoing task difficulty, which is much higher in studies of mind-wandering than the vigilance tasks used to study IAMs and IFTs. It will be interesting therefore to manipulate the presence and absence of incidental cue words and the difficulty levels of the vigilance task in participants with and without ADHD to address these issues.

Taken together, these null effects lead us to the main theoretically relevant question, namely, is it possible that we have got the cognitive inhibition dependency hypothesis of IAMs and IFTs, in general, and ADHD hypothesis, in particular, all wrong? Based on the results of the present study, and in line with initial findings by Barzykowski et al. (2019a), we are inclined to suggest that the occurrence of IAMs and IFTs may not depend on the putative inhibition mechanism as suggested in the literature (see also Nixon et al., 2021, for a similar non-significant relationship between the number of reported trauma intrusions during the ongoing reading task and scores on inhibitory control as measured by SART in participants with PTSD and with low and high levels of post-traumatic stress). We are not arguing that the cognitive inhibition dependency hypothesis of IAMs and IFTs should be entirely disregarded ~~entirely,~~ because of the null effects obtained so far, but rather that the relationship between inhibitory control and spontaneous thoughts may be more complex and less straightforward than previously thought. Is it possible, for example, that the difficulty of ongoing task and high levels of on-task concentration reduce the efficacy with which incidental cues are noticed in the first place, thus, obviating the need for any inhibitory mechanism?

This is a potentially compelling explanation, especially when considering the nature of the brain's default mode network (DMN) that is thought to underlie or facilitate the occurrence of task-unrelated thoughts (e.g. Christoff, 2012; Buckner, Andrews-Hanna, & Schacter, 2008; Kvavilashvili, Niedźwieńska, Gilbert & Marksotamou, 2020; Raichle, 2015; Stawarczyk et al., 2011). The DMN is comprised of several interconnected brain regions that show higher levels of activity at rest and, conversely, increased levels of deactivation when we concentrate on the external task requiring cognitive resources and attention. Therefore, incidental cues may lose their power to elicit any IAMs and IFTs due to this deactivation of DMN during ongoing tasks requiring medium to high levels of attention (but the relationship between cognitive load and DMN may be more complex, see Jenkins, 2019). For instance, results of some previous studies suggest that even relatively undemanding activities, such as attending to predictable stimuli in the external environment, can substantially reduce the number of involuntary cognitions in one's mind (e.g. Floridou, Williamson, & Stewart, 2017; Vannucci, Pelagatti, Hańczakowski and Chiorri, 2019).

Furthermore, Sörqvist and Marsh (2015) have suggested that high levels of on-task concentration significantly reduce the chances of processing background information and thus make participants less susceptible to the irrelevant (distracter) stimuli presented in the background. Since in the present study participants were exhibiting medium levels of concentration on the vigilance task requiring certain amount of cognitive resources and attention, it is possible that they were less likely to experience IAMs and IFTs in response to external cues independently from the levels of cognitive inhibitory control. This may also explain why we did not replicate a positive relationship between IAMs and weak inhibitory control reported by Kamiya (2014) and Verwoerd and Wessel (2007) because they either used questionnaire methods to evaluate the frequency of IAMs across various everyday attention-demanding situations (Verwoerd & Wessel, 2007) or recorded IAMs during a fairly undemanding activity such as walking (Kamiya, 2014). To further assess this possibility, future studies could manipulate the difficulty level of the vigilance task. For instance, in an additional control group participants would not have to concentrate and detect any target patterns of vertical lines in which case, if this rationale is right, participants' DMN activity levels would be higher than in a standard vigilance task condition, leading to reliably higher frequency of reported IAMs and IFTs.

Another possibility, suggested by Barzykowski et al. (2019a) is that the task parameters were too easy for all participants. The idea here is that the inhibitory control mechanism switches on only when we are engaged in attentionally very demanding activities (e.g. writing a paper), because these are the activities that can be negatively affected by the occurrence of involuntary thoughts. Means presented in Table 1 show that the vigilance task was indeed rated by participants as not very difficult and demanding, thus future studies might benefit from manipulating the difficulty level of the vigilance task in the other direction, i.e., making it much more attentionally demanding (as in Barzykowski & Niedźwieńska, 2018a; Vannucci et al., 2019). Barzykowski and Niedźwieńska (2018a) provide some initial support for this idea by showing that participants reported a higher proportion of IAMs (out of all the spontaneous task-unrelated thoughts reported) in the attentionally demanding condition of a standard vigilance task.

In summary, it appears that several variables may influence the occurrence of IFTs and IAMs in addition to, or instead of, the putative inhibitory control mechanism. Therefore, the results of studies, conducted so far, show that the role of the inhibitory mechanism is perhaps not as strong as suggested by the inhibitory control dependency hypothesis and there may be other cognitive mechanisms that underlie the retrieval of IAMs and IFTs.

4.2. Some limitations, design considerations and avenues for future research

When considering the results of the present study, some limitations and possible improvements may be taken into account. First, one potential criticism of the study is that we assigned participants to discreet groups based on their inhibition scores rather than examining the relationship between participants' inhibition scores and the number of reported involuntary cognitions in the entire sample tested online. We admit that splitting participants into different groups may be problematic, especially when the extreme groups design is used (i.e., splitting a sample into two groups of bottom and top scoring participants). Despite problems associated with the extreme groups design (for discussion see Fisher et al., 2020; Preacher et al., 2005), this type of dichotomising has been fairly popular in some areas of cognitive psychology, particularly in research on individual differences in working memory (for a discussion see Conway et al., 2005, pp. 782-783; for empirical studies on working memory using this approach see Berry et al., 2019; Endres et al., 2015; Engle et al., 1992; Kiefer et al., 2005; Mella et al., 2015; Stout et al., 2018; Yu et al., 2014). This is because the extreme groups design is a cost-effective way of testing whether a given relationship does or does not exist irrespective of the strength of the relationship (Conway et al., 2005; Fischer et al., 2020; Preacher et al., 2005). As pointed out by Preacher et al. (2005), this approach is particularly appropriate in situations where there is little prior empirical research to guide theory development, and/or there are limited resources for testing very large samples (when the expected effect sizes are very small). Since we wanted to verify whether the frequency of involuntary past and future thoughts depended on the putative inhibitory control mechanism, using discrete groups was the best possible solution for achieving this goal. It is also worth pointing out that we used all the necessary precautions, recommended in the literature, when adopting the extreme groups design. For example, by including into the design a third group with scores in the middle range of the distribution (together with an additional group of participants with ADHD), we were able to "substantially mitigate inflation of the estimated population effect size" that is a typical problem arising from the extreme groups design (Fisher et al., 2005, p. 7). In addition, to increase the accuracy of assigning participants to discreet groups, the inhibitory control was assessed by two well-known tasks measuring this variable rather than just one task, in line with Conway et al.'s (2005) recommendations. Finally, we employed the strategy of assigning participants to discreet groups on a priori grounds (Fisher et al. 2020).

Another possible criticism of the study is that our participants were sampled from a very high end of the distribution of cognitive inhibitory capacity, which would invalidate our division of a sample into three groups of low, medium and high inhibitory control capacity (i.e., even individuals in the low capacity group would have better inhibitory control than what is observed in the general population). If this was indeed the case, then we should expect all three groups (i.e. low, middle and high) to be significantly better than the ADHD group. However, as shown in section 3.1 (see also Table 1), participants in the low inhibitory control capacity group were poorer at inhibiting than participants with the ADHD spectrum.

Third, the interference ratio scores obtained in the online and laboratory sessions were reliably but weakly correlated (see Footnote 2), which may challenge the notion of cognitive control being a stable individual difference variable or, alternatively, may raise concerns about the reliability of the Stroop and Flanker tasks and difficulties in establishing an overall measure of the inhibitory control capacity (e.g., Hedge et al., 2018a; Paap & Sawi, 2016; Enkavi et al., 2019). While this issue exceeds the scope of the present paper, it should be emphasised that such a discrepancy could be caused by several factors, most importantly by differences in the online and laboratory testing. For example, some participants in the online low inhibitory group might have performed the online tasks under sub-optimal conditions (due to noise, interruptions) compared to laboratory-based testing conditions. Thus, we argue that since our main goal was to test individuals who were significantly different from each other in terms of their inhibitory control capacity at the time of laboratory testing, by re-grouping participants on their laboratory-based scores we directly attained this particular goal. Even if there was no stable measure of inhibitory control ability, by examining participants' inhibitory control immediately after the past and future thoughts were tested, we feel confident that at least the differences in the cognitive inhibitory control observed in the laboratory lasted long enough to have noticeable effects on IAMs and IFTs during the preceding vigilance task.

Fourth, one may argue that when selecting people with ADHD spectrum, we should have used higher and more severe criteria for identifying participants as individuals with ADHD spectrum. This idea is based on the assumption that there could be more extreme cut off point on the spectrum of ADHD severity beyond which inhibitory control breaks down, leading individuals to being systematically flooded by task-unrelated thoughts about the past and future. Another idea would be to study individuals who were clinically diagnosed with ADHD. However, according to Kooij et al. (2005), the cut-off of four or more symptoms of inattention or hyperactivity-impulsivity, that was used in the present study, is sufficient for diagnosing ADHD in adults, and hence it may be argued that these individuals would have most likely received the same ADHD diagnoses if they were tested by clinicians. Importantly, previous mind-wandering studies (e.g. Jonkman et al., 2017) have also used predominantly undergraduate samples based on their scores on various ADHD measures and questionnaires rather than clinical assessment. It would be reasonable to differentiate specific sub-groups of ADHD individuals especially those with predominantly inattentive ADHD type from predominantly hyperactive/impulsive type (i.e. with mainly poor response inhibitory control). For example, Jonkman et al. (2017), who investigated the relationship between mind-wandering and ADHD-symptomatology, included only individuals with high or low ADHD-

Inattention symptoms while keeping the Hyperactivity/Impulsivity symptoms in the normal range. Thus, since increased instances of mind-wandering were related to ADHD-Inattention symptomatology, it is possible that increased frequency of IAMs and IFTs would be a key-feature of mostly Hyperactivity/Impulsivity symptomatology, if ~~only~~ it was only limited by the inhibitory control. While this does not weaken our main findings, future studies could control for these possibilities by including in the study not only participants with the most severe ADHD symptoms, but also examining specific sub-types of ADHD symptomatology, and controlling for ADHD spectrum symptoms across all experimental groups.

Another intriguing question, emerging from our study, is whether individuals with ADHD experience IAMs and IFTs more frequently in their everyday life (i.e., outside the laboratory)? Existing studies on mind-wandering and anecdotal evidence suggest an affirmative answer to this question in contrast to our findings and, therefore, future studies could use experience sampling methods (similar to Warden et al., 2019) in which ADHD individuals are asked to report about their mentation at several repeated occasions in their everyday context, and compare the data to the data obtained in a laboratory session with a vigilance task.

Finally, an important theoretical question, emerging from the present study and the current literature (e.g., Hedge et al., 2018c, 2020; Enkavi et al., 2019; Paap & Sawi, 2016; Rey-Mermet et al., 2018; Rouder & Haaf, 2019) is whether a general inhibitory control ability exists and can be reliably measured in experimental settings. While keeping this in mind, the present findings mainly showed that involuntary past and future thoughts may not be well predicted by performance scores on well-known inhibitory control tasks although, as already discussed in the introduction, they have been shown to predict performance in multiple cognitive tasks and behaviours. However, this is not to say unequivocally that inhibitory control capacity does not contribute and/or regulate involuntary past and future thinking. There is still need for gaining a better understanding of the nature of cognitive inhibition phenomena (i.e., unitary vs. diverse), its complexity and significance for human everyday cognition and behaviour. Therefore, more studies are needed to address the question about the inhibitory control dependency of the past and future thinking. For instance, while studying the relationship between inhibitory control and past and future thinking, future studies could concurrently include other variables that have ~~been~~ prove~~d~~n to be highly influenced by inhibitory control (e.g., behavioural impulsivity measures or questionnaires etc.), which would facilitate the interpretation of null effects observed in the present study. Also, future studies might benefit from applying a more nuanced understanding of the nature of inhibitory ability resulting in using various experimental and questionnaire methods to measure different instances of inhibitory control, such as, for example, negative priming which seems to be less volitional (but for further discussion see Frings et al., 2015).

4.3. Final conclusions

We have investigated whether the frequency of IAMs and IFTs depend on the inhibitory control mechanism. To the best of our knowledge, this is the first study that addressed this question by applying an individual difference approach and by including into the study participants with ADHD spectrum symptoms. First of all, the findings of the present study and the study by Barzykowski et al. (2019a) suggest that inhibition may not strongly affect the occurrence of spontaneous thoughts, and therefore, they do not support the idea that involuntary mental contents rely strongly on the special inhibitory control mechanism. One potentially interesting avenue for research, as suggested earlier, is to adopt an individual differences approach, as in the present study, and manipulate the difficulty level of the vigilance task to assess the possibility that the weak inhibitory control will increase the IFTs and IAMs during the difficult, but not the standard version of the vigilance task. We believe that this research avenue may ultimately provide important insights into cognitive mechanisms of involuntary cognitions.

References

Abutalebi, J., & Green, D. (2007). Bilingual language production: The neurocognition of language representation and control. *Journal of Neurolinguistics, 20,* 242-275.

Allom, V., Mullan, B., & Hagger, M. (2016). Does inhibitory control training improve health behaviour? A meta-analysis. *Health Psychology Review, 10(2),* 168-186.

Anzman, S. L., & Birch, L. L. (2009). Low inhibitory control and restrictive feeding practices predict weight outcomes. *The Journal of Pediatrics, 155(5),* 651-656.

Baird, B., Smallwood, J., Fishman, D. J. F., Mrazek, M. D., & Schooler, J. W. (2013). Unnoticed intrusions: Dissociations of meta-consciousness in thought suppression. *Consciousness and Cognition, 22(3),* 1003–1012. https://doi.org/10.1016/j.concog. 2013.06.009.

Barkley, R. A. (1997). Behavioral inhibition, sustained attention, and executive function: Constructing a unified theory of ADHD. *Psychological Bulletin, 121,* 65–94. https://doi.org/10.1037/0033-2909.121.1.65.

Barzykowski, K. (2014). How can we catch spontaneous memories: A review of methodological issues in involuntary autobiographical memories studies. In *SAGE research methods cases.* London: SAGE. https://dx.doi.org/10.4135/978144627305013517801.

Barzykowski, K., & Niedźwieńska, A. (2012). Przegląd badań nad mimowolnymi wspomnieniami autobiograficznymi. Perspektywy badawcze. [Review of studies on involuntary autobiographical memories. Research perspectives]. *Roczniki Psychologiczne [Annals of Psychology], 1(XV),* 55–74.

Barzykowski, K., & Niedźwieńska, A. (2016). The effects of instruction on the frequency and characteristics of involuntary autobiographical memories. *PloS one, 11.* https://doi.org/10.1371/journal.pone.0157121.

Barzykowski, K., & Niedźwieńska, A. (2018a). Involuntary autobiographical memories are relatively more often reported during high cognitive load tasks. *Acta Psychologica, 182,* 119-128. https://doi.org/10.1016/j.actpsy.2017.11.014.

Barzykowski, K., & Niedźwieńska, A. (2018b). Priming involuntary autobiographical memories in the lab. *Memory, 26,* 277-289. https://doi.org/10.1080/09658211.2017.1353102.

Barzykowski, K., & Staugaard, S. R. (2016). Does retrieval intentionality really matter? Similarities and differences between involuntary memories and directly and generatively retrieved voluntary memories. *British Journal of Psychology, 107,* 519-536. https://doi.org/10.1111/bjop.12160.

Barzykowski, K., & Staugaard, S. R. (2018). How intention and monitoring your thoughts influence characteristics of autobiographical memories. *British Journal of Psychology, 109,* 321-340. https://doi.org/10.1111/bjop.12259.

Barzykowski, K., Niedźwieńska, A., & Mazzoni, G. (2019). How intention to retrieve a memory and expectation that a memory will come to mind influence the retrieval of autobiographical memories. *Consciousness and cognition, 72,* 31-48. https://doi.org/10.1016/j.concog.2019.03.011.

Barzykowski, K., Radel, R., Niedźwieńska, A., & Kvavilashvili, L. (2019a). Why are we not flooded by involuntary thoughts about the past and future? Testing the cognitive inhibition dependency hypothesis. *Psychological research, 83,* 666-683. https://doi.org/10.1007/s00426-018-1120-6.

Barzykowski, K., Riess, M., Hajdas, S. & Niedźwieńska, A. (2019b). School in our memory: Do we remember the middle and high school time differently? *Journal of Cognitive Psychology, 31(4),* 438-452. https://doi.org/10.1080/20445911.2019.1621320.

Berntsen, D. (1996). Involuntary autobiographical memories. *Applied Cognitive Psychology, 10,* 435-454. https://doi.org/10.1002/(SICI)1099-0720(199610)10:5<435::AID-ACP408>3.0.CO;2-L.

Berntsen, D. (2019). Spontaneous future cognitions: An integrative review. *Psychological Research, 83,* 651-665. https://doi.org/10.1007/s00426-018-1127-z.

Berntsen, D., & Jacobsen, A. S. (2008). Involuntary (spontaneous) mental time travel into the past and future. *Consciousness and cognition, 17,* 1093-1104. https://doi.org/10.1016/j.concog.2008.03.001.

Berry, E.D.J., Allen, R.J., Mon-Williams, M. and Waterman, A.H. (2019), Cognitive Offloading: Structuring the Environment to Improve Children's Working Memory Task Performance. *Cognitive Science, 43:* e12770. https://doi.org/10.1111/cogs.12770

Broadbent, D. E., Cooper, P. F., Fitzgerald, P., & Parkes, K. R. (1982). The cognitive failures questionnaire (CFQ) and its correlates. *British Journal of Clinical Psychology, 21,* 1–16. https://doi.org/10.1111/j.2044-8260.1982.tb01421.x.

Brzozowski, P. (2010). Skala Uczuć Pozytywnych i Negatywnych (SUPIN). Polska adaptacja skali PANAS Dawida Watsona i Lee Anny Clark. *Podręcznik [The manual of the Polish adaptation of SUPIN. Positive and negative affect schedule (PANAS).].* Warszawa: Pracownia Testów Psychologicznych.

Buckner, R. L., Andrews-Hanna, J. R., & Schacter, D. L. (2008). The brain's default network: Anatomy, function, and relevance to disease. *Annals of New York Academy of Science, 1124,* 1-38.

Carson, S. H., Peterson, J. B., & Higgins, D. M. (2003). Decreased Latent Inhibition Is Associated With Increased Creative Achievement in High-Functioning Individuals. *Journal of Personality and Social Psychology, 85,* 499–506. https://doi.org/10.1037/0022-3514.85.3.499.

Christoff, K. (2012). Undirected thought: Neural determinants and correlates. *Brain Research, 1428,* 51-59.

Chuderski, A., Taraday, M., Nęcka, E., & Smoleń, T. (2012). Storage capacity explains fluid intelligence but executive control does not. *Intelligence, 40,* 278-295. https://doi.org/10.1016/j.intell.2012.02.010.

Cole, S. N., Staugaard, S. R., & Berntsen, D. (2016). Inducing involuntary and voluntary mental time travel using a laboratory paradigm. *Memory & Cognition, 44,* 376-389. https://doi.org/10.1037/1+B18.

Cole, S., & Kvavilashvili, L. (2019). Spontaneous future cognition: The past, present and future of an emerging topic. *Psychological Research 83,* 631–650. https://doi.org/10.1007/s00426-019-01193-3.

Cole, S., & Kvavilashvili, L. (2021). Spontaneous and deliberate future thinking: a dual process account. *Psychological Research, 85,* 464-479.

Conway, A. R., Kane, M. J., Bunting, M. F., Hambrick, D. Z., Wilhelm, O., & Engle, R. W. (2005). Working memory span tasks: A methodological review and user's guide. *Psychonomic Bulletin & Review, 12(5),* 769–786. http://doi.org/10.1037/0096-3445.133.2.189

Conway, M. A. (2008). Exploring episodic memory. *Handbook of behavioral neuroscience, 18,* 19-29. https://doi.org/10.1016/S1569-7339(08)00202-6.

Conway, M. A. (2009). Episodic memories. *Neuropsychologia, 47,* 2305-2313. https://doi.org/10.1016/j.neuropsychologia.2009.02.003.

Conway, M. A., & Jobson, L. (2012). On the nature of autobiographical memory. In D. Berntsen & D. C. Rubin (Eds.), *Understanding autobiographical memory: Theories and approaches* (pp. 54–69). Cambridge, England: Cambridge University Press.

Conway, M. A., & Pleydell-Pearce, C. W. (2000). The construction of autobiographical memories in the self-memory system. *Psychological review, 107,* 261. https://doi.org/10.1037/0033-295X.107.2.261.

Draheim, C. et al. (2016). Combining reaction time and accuracy: The relationship between working memory capacity and task switching as a case example. *Perspectives on Psychological Science, 11(1),* 133-155. https://doi.org/10.1177%2F1745691615596990.

Draheim, C et al. (2021). A toolbox approach to improving the measurement of attention control. *Journal of Experimental Psychology: General, 150(2),* 242-275. https://doi.org/10.1037/xge0000783.

D'Argembeau, A., &A2 Van der Linden, M. (2004). Influence of Affective Meaning on Memory for Contextual Information. *Emotion, 4,* 173–188. https://doi.org/10.1037/1528-3542.4.2.173.

Deberdt, W., Thome, J., Lebrec, J., Kraemer, S., Fregenal, I., Ramos-Quiroga, JA., Arif, M. (2015). Prevalence of ADHD in nonpsychotic adult psychiatric care (ADPSYC): a multinational cross-sectional study in Europe. *BMC Psychiatry 15,* 242. https://doi.org/10.1186/s12888-015-0624-5.

Depue, B. E., Burgess, G. C., Willcutt, E. G., Ruzic, L., & Banich, M. T. (2010). Inhibitory control of memory retrieval and motor processing associated with the right lateral prefrontal cortex: Evidence from deficits in individuals with ADHD. *Neuropsychologia, 48(13),* 3909-3917.

Endres, M.J., Houpt, J.W., Donkin, Ch., & Finn, P.R. (2015). Working memory capacity and redundant information processing efficiency. *Frontiers in Psychology, 6(JAN),* 1–12. https://doi.org/10.3389/fpsyg.2015.00594

Engle, R. W., Cantor, J., & Carullo, J. J. (1992). Individual differences in working memory and comprehension: A test of four hypotheses. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 18(5),* 972–992. https://doi.org/10.1037/0278-7393.18.5.972

Enkavi, A. Z., et al.. (2019). Large-scale analysis of test-retest reliabilities of self-regulation measures. *Proceedings of the National Academy of Sciences, 116(12),* 5472- 5477. https://doi.org/10.1073/pnas.1818430116.

Epstein, J.N., Johnson, D.E., Conners, C.K. (2001). *CAADID: Conners' Adult ADHD Diagnostic Interview for DSM-IV.* Multi-Health systems Inc.

Eriksen, B. A., & Eriksen, C. W. (1974). Effects of noise letters upon the identification of a target letter in a nonsearch task. *Perception & psychophysics, 16,* 143-149.

Faust, M. E., et al. (1999). Individual differences in information-processing rate and amount: Implications for group differences in response latency. *Psychological Bulletin, 125(6),* 777-799. https://psycnet.apa.org/doi/10.1037/0033-2909.125.6.777

Finnbogadóttir, H., & Berntsen, D. (2013). Involuntary future projections are as frequent as involuntary memories, but more positive. *Consciousness and Cognition, 22,* 272-280. https://doi.org/10.1016/j.concog.2012.06.014.

Fisher, J. E., Guha, A., Heller, W., & Miller, G. A. (2020). Extreme-groups designs in studies of dimensional phenomena: Advantages, caveats, and recommendations. *Journal of abnormal psychology, 129(1),* 14–20. https://doi.org/10.1037/abn0000480

Floridou, G. A., Willimson, V. J., & Stewart, L. (2017). A novel indirect method for capturing involuntary musical imagery under varying cognitive load. *The Quarterly Journal of Experimental Psychology, 70,* 2189–2199. https://doi.org/10.1080/17470218.2016.1227860.

Franklin, M. S., Mooneyham, B. W., Baird, B., & Schooler, J. W. (2014). Thinking one thing, saying another: The behavioral correlates of mind-wandering while reading aloud. Psychonomic *Bulletin & Review, 21,* 205-210. https://doi.org/10.3758/s13423-013-0468-2.

Franklin, M. S., Mrazek, M. D., Anderson, C. L., Johnston, C., Smallwood, J., Kingstone, A., & Schooler, J. W. (2017). Tracking Distraction: The Relationship Between Mind-Wandering, Meta-Awareness, and ADHD Symptomatology. *Journal of Attention Disorders, 21,* 475–486. https://doi.org/10.1177/1087054714543494.

Friedman, N. P., & Miyake, A. (2004). The relations among inhibition and interference control functions: a latent-variable analysis. *Journal of experimental psychology: General, 133,* 101. https://doi.org/10.1037/0096-3445.133.1.101.

Friedman, N. P., & Miyake, A. (2017). Unity and diversity of executive functions: Individual differences as a window on cognitive structure. *Cortex, 86,* 186-204. https://doi.org/10.1016/j.cortex.2016.04.023.

Frings, C., Schneider, K. K., & Fox, E. (2015). The negative priming paradigm: An update and implications for selective attention. *Psychonomic Bulletin and Review*, *22*(6), 1577–1597. https://doi.org/10.3758/s13423-015-0841-4.

Hagger, M. S., Wood, C., Stiff, C., & Chatzisarantis, N. L. D. (2010). Ego depletion and the strength model of self-control: A meta-analysis. *Psychological Bulletin, 136,* 495–525. https://doi.org/10.1037/a0019486.

Hasher, L., Lustig, C., & Zacks, R. (2007). Inhibitory mechanisms and the control of attention. In A. R. A. Conway, C. Jarrold, M. J. Kane (Eds.) & A. Miyake & J. N. Towse (Ed.), *Variation in working memory* (p. 227–249). Oxford University Press.

Hasher, L., Zacks, R. T., & May, C. P. (1999). Inhibitory control, circadian arousal, and age. In D. Gopher & A. Koriat (Eds.), *Attention and performance XVII: cognitive regulation of performance: interaction of theory and application* (pp. 653–675). Cambridge: The MIT Press.

Hedge, C., Powell, G., & Sumner, P. (2018a). The mapping between transformed reaction time costs and models of processing in aging and cognition. Psychology and Aging, 33(7), 1093-1104. http://dx.doi.org/10.1037/pag0000298.

Hedge, C., Powell, G. & Sumner, P. (2018b). The reliability paradox: Why robust cognitive tasks do not produce reliable individual differences. *Behavior Research Methods, 50(3),* 1166-1186. https://doi.org/10.3758/s13428-017-0935-1.

Hedge, C., Powell, G., Bompas, A., & Sumner, P. (2020). Strategy and processing speed eclipse individual differences in control ability in conflict tasks. [Preprint]. https://doi.org/10.31234/osf.io/vgpxq.

Hedge, C., Powell, G., Bompas, A., Vivian-Griffiths, S., & Sumner, P. (2018b). Low and variable correlation between reaction time costs and accuracy costs explained by accumulation models: Meta-analysis and simulations. Psychological Bulletin, 144(11), 1200-1227. http://dx.doi.org/10.1037/bul0000164 .

Houben, K. (2011). Overcoming the urge to splurge: Influencing eating behavior by manipulating inhibitory control. *Journal of Behavior Therapy and Experimental Psychiatry, 42,* 384–388. https://doi.org/10.1016/j.jbtep.2011.02.008.

Houben, K., & Wiers, R. W. (2009). Response inhibition moderates the relationship between implicit associations and drinking behavior. *Alcoholism: Clinical and Experimental Research, 33,* 1–8.

Hsieh, I. J., & Chen, Y. Y. (2017). Determinants of aggressive behavior: Interactive effects of emotional regulation and inhibitory control. *PloS One, 12(4),* e0175651.

Jackson, J. D., Weinstein, Y., & Balota, D. A. (2013). Can mind-wandering be timeless? Atemporal focus and aging in mind-wandering paradigms. *Frontiers in Psychology, 4,* 742.

Jaeschke, R., Brudkiewicz, P., Bron, A., Kooij, J.J.S. (2016). *Polish translation of the Diagnostic Interview for ADHD in adults (DIVA 2.0).* Hague, Netherlands: Foundation, PsyQ. DOI: 10.13140/RG.2.1.3862.6165.

Jenkins, A. C. (2019). Rethinking cognitive load: A default-mode network perspective. *Trends in Cognitive Sciences*, *23*(7), 531–533. https://doi.org/10.1016/j.tics.2019.04.008.

Jongen, E. M. M., Brijs, K., Komlos, M., Brijs, T., & Wets, G. (2011). Inhibitory control and reward predict risky driving in young novice drivers - A simulator study. *Procedia - Social and Behavioral Sciences, 20,* 604–612. https://doi.org/10.1016/j.sbspro.2011.08.067.

Jonkman, L. M., Markus, C. R., Franklin, M. S., & Van Dalfsen, J. H. (2017). Mind wandering during attention performance: effects of ADHD-inattention symptomatology, negative mood, ruminative response style and working memory capacity. *PLoS One, 12(7),* 1–19. https://doi.org/10.1371/journal.pone.0181213.

Joormann, J. (2010). Cognitive inhibition and emotion regulation in depression. *Current Directions in Psychological Science, 19(3),* 161-166.

Joormann, J., & Gotlib, I. H. (2010). Emotion regulation in depression: relation to cognitive inhibition. *Cognition and Emotion, 24(2),* 281-298.

Kalanthroff, E., Cohen, N., & Henik, A. (2013). Stop feeling: inhibition of emotional interference following stop-signal trials. *Frontiers in Human Neuroscience, 7,* 78.

Kamiya, S. (2014). Relationship between frequency of involuntary autobiographical memories and cognitive failure. *Memory, 22,* 839–851. https://doi.org/10.1080/09658211.2013.838630.

Kiefer, M., Ahlegian, M., & Spitzer, M. (2005). Working Memory Capacity, Indirect Semantic Priming, and Stroop Interference: Pattern of Interindividual Prefrontal Performance Differences in Healthy Volunteers. *Neuropsychology, 19(3),* 332–344. https://doi.org/10.1037/0894-4105.19.3.332

King, J. A., Colla, M., Brass, M., Heuser, I., & von Cramon, D. Y. (2007). Inefficient cognitive control in adult ADHD: Evidence from trial-by-trial Stroop test and cued task switching performance. *Behavioral and Brain Functions, 3,* 1–19. https://doi.org/10.1186/1744-9081-3-42.

Kooij, J. J. S. (2012). *Adult ADHD: Diagnostic assessment and treatment (3rd ed.).* London, England: Springer-Verlag. doi: 10.1007/978-1-4471-4138-9.

Kooij, J. S., Buitelaar, J. K., van den Oord, E. J. C. G., Furer, J. W., Rijnders, C. A. T., & Hodiamont, P. P. (2005). Internal and external validity of attention-deficit hyperactivity disorder in a population-based sample of adults. *Psychological Medicine, 35,* 817-827. https://doi.org/10.1017/S003329170400337X.

Kooij, J.J.S., Francken, & M.H. (2010). *Diagnostisch Interviewvoor ADHD (DIVA) bij volwassenen 2.0. DIVA.* Hague, Netherlands: Foundation, PsyQ.

Lansbergen, M. M., Kenemans, J. L., & Van Engeland, H. (2007). Stroop interference and attention-deficit/hyperactivity disorder: A review and meta-analysis. *Neuropsychology, 21,* 251–262. https://doi.org/10.1037/0894-4105.21.2.251.

Logan, G. D., Schachar, R. J., & Tannock, R. (1997). Impulsivity and inhibitory control. *Psychological Science, 8(1),* 60-64.

Mace, J. H. (2004). Involuntary autobiographical memories are highly dependent on abstract cuing: the Proustian view is incorrect. *Applied Cognitive Psychology, 18 (7),* 893.899.

Mace, J. H., & Petersen, E. P. (2020). Priming autobiographical memories: How recalling the past may affect everyday forms of autobiographical remembering. *Consciousness and Cognition, 85,* 103018. doi:10.1016/j.concog.2020.103018.

Mace, J. H., & Unlu, M. (2020). Semantic-to-autobiographical memory priming occurs across multiple sources: Implications for autobiographical remembering. *Memory & Cognition, 48,* 931-941. https://doi. org/10.3758/s1342 1-020-01029 -1.

MacLeod, C. M. (1991). Half a century of research on the Stroop effect: An integrative review. *Psychological Bulletin, 109,* 163–203. https://doi.org/10.1037/0033-2909.109.2.163.

Mazzoni, G., Vannucci, M., & Batool, I. (2014). Manipulating cues in involuntary autobiographical memory: Verbal cues are more effective than pictorial cues. *Memory and Cognition, 42,* 1076–1085. https ://doi.org/10.3758/s1342 1-014-0420-3.

Mella, N., Fagot, D., Lecerf, T. et al. Working memory and intraindividual variability in processing speed: A lifespan developmental and individual-differences study. *Memory and Cognition, 43,* 340–356 (2015). https://doi.org/10.3758/s13421-014-0491-1

Mercier, J., Pivneva, I., & Titone, D. (2014). Individual differences in inhibitory control relate to bilingual spoken word processing. *Bilingualism: Language and Cognition, 17(1),* 89–117. https://doi.org/10.1017/S1366728913000084.

Miller, N. V., Hane, A. A., Degnan, K. A., Fox, N. A., & Chronis- Tuscano, A. (2019). Investigation of a developmental pathway from infant anger reactivity to childhood inhibitory control and ADHD symptoms: interactive effects of early maternal caregiving. *Journal of Child Psychology and Psychiatry, 60(7),* 762-772.

Muraven, M., & Baumeister, R. F. (2000). Self-regulation and depletion of limited resources: Does self-control resemble a muscle? *Psychological Bulletin, 126,* 247–259. https://doi.org/10.1037/0033-2909.126.2.247.

Murphy, P., & Schachar, R. (2000). Use of self-ratings in the assessment of symptoms of Attention Deficit/Hyperactivity Disorder in adults. *American Journal of Psychiatry, 7,* 1156–1159. https://doi.org/10.1176/appi.ajp.157.7.1156.

Nederkoorn, C., Houben, K., Hofmann, W., Roefs, A., & Jansen, A. (2010). Control yourself or just eat what you like?: weight gain over a year is predicted by an interactive effect of response inhibition and implicit preference for snack foods. *Health Psychology, 29,* 389–393.

Niedźwieńska, A., & Kvavilashvili, L. (2018). Reduced mind-wandering in Mild Cognitive Impairment: Testing the spontaneous retrieval deficit hypothesis. *Neuropsychology, 32(6),* 711-723. DOI: http://dx.doi.org/10.1037/neu0000457.

Nixon, R. D. V., Roberts, L. N., Sun, Y-T. J., & Takarangi, M. (2021). Are individuals always aware of their trauma-related intrusive thoughts? A study of meta-awareness. Behavior Therapy, 52, 874-882.

Pauli-Pott, U., Albayrak, Ö., Hebebrand, J., & Pott, W. (2010). Association between inhibitory control capacity and body weight in overweight and obese children and adolescents: dependence on age and inhibitory control component. *Child Neuropsychology, 16,* 592-603. https://doi.org/10.1080/09297049.2010.485980.

Paap, K. R., & Sawi, O. (2016). The role of test-retest reliability in measuring individual and group differences in executive functioning. *Journal of Neuroscience Methods, 274,* 81- 93. https://doi.org/10.1016/j.jneumeth.2016.10.002.

Payne, B. K. (2005). Conceptualizing control in social cognition: how executive functioning modulates the expression of automatic stereotyping. *Journal of Personality and Social Psychology, 89,* 488–503. https://doi.org/10.1037/0022-3514.89.4.488.

Pettersson, R., Söderström, S., & Nilsson, K. W. (2018). Diagnosing ADHD in Adults: An Examination of the Discriminative Validity of Neuropsychological Tests and Diagnostic Assessment Instruments. *Journal of Attention Disorders, 22(11),* 1019–1031. https://doi.org/10.1177/1087054715618788.

Pettigrew, C., & Martin, R. C. (2014). Cognitive declines in healthy aging: Evidence from multiple aspects of interference resolution. *Psychology and Aging, 29,* 187–204. http://dx.doi.org/10.1037/a0036085.

Preacher, K., Rucker, D., MacCallum, R., & Nicewander, W.A. (2005). Use of the extreme groups approach: a critical reexamination and new recommendations. *Psychological methods, 10(2),* 178-92.

Plimpton, B., Patel, P., & Kvavilashvili, L. (2015). Role of triggers and dysphoria in mind-wandering about past, present and future: A laboratory study. Consciousness and *Cognition, 33,* 261-276. https://doi.org/10.1016/j.concog.2015.01.014.

Radel, R., Davranche, K., Fournier, M., & Dietrich, A. (2015). The role of (dis)inhibition in creativity: Decreased inhibition improves idea generation. *Cognition, 134,* 110–120. https://doi.org/10.1016/j.cognition.2014.09.001.

Radel, R., Gruet, M., & Barzykowski, K. (2019). Testing the ego-depletion effect in optimal conditions. *PLoS ONE, 14(3),* 1-15. DOI: https://doi.org/10.1371/journal.pone.0213026

Raichle, M. E. (2015). The brain's default mode network. *The Annual Review of Neuroscience, 38,* 433-437.

Ramos-Quiroga, J. A., Nasillo, V., Richarte, V., Corrales, M., Palma, F., Ibáñez, P., … Kooij, J. J. S. (2019). Criteria and Concurrent Validity of DIVA 2.0: A Semi-Structured Diagnostic Interview for Adult ADHD. *Journal of Attention Disorders, 23,* 1126–1135. https://doi.org/10.1177/1087054716646451.

Rey-Mermet, A., Gade, M., & Oberauer, K. (2018). Should we stop thinking about inhibition? Searching for individual and age differences in inhibition ability. *Journal of Experimental Psychology: Learning Memory and Cognition, 44(4),* 501–526. https://doi.org/10.1037/xlm0000450.

Riley, E., Esterman, M., Fortenbaugh, F. C., & DeGutis, J. (2017). Time-of-day variation in sustained attentional control. *Chronobiology international, 34(7),* 993–1001. https://doi.org/10.1080/07420528.2017.1308951

Robertson, I. H., Manly, T., Andrade, J., Baddeley, B. T., & Yiend, J. (1997). ''Oops!'': Performance correlates of everyday attentional failures in traumatic brain injured and normal subjects. *Neuropsychologia, 35,* 747–758.

Rouder, J. N., & Haaf, J. M. (2019). A psychometrics of individual differences in experimental tasks. *Psychonomic Bulletin & Review, 26(2),* 452-467. https://doi.org/10.3758/s13423-018-1558-y

Schachar, R., Mota, V. L., Logan, G. D., Tannock, R., & Klim, P. (2000). Confirmation of an inhibitory control deficit in attention-deficit/hyperactivity disorder. *Journal of abnormal child psychology, 28(3),* 227-235.

Schachar, R., Tannock, R., Marriott, M., & Logan, G. (1995). Deficient inhibitory control in attention deficit hyperactivity disorder. *Journal of abnormal child psychology, 23(4),* 411-437.

Schlagman, S., & Kvavilashvili, L. (2008). Involuntary autobiographical memories in and outside the laboratory: How different are they from voluntary autobiographical memories? *Memory & Cognition, 36,* 920-932. https://doi.org/10.3758/MC.36.5.920.

Schlagman, S., Kliegel, M., Schulz, J., & Kvavilashvili, L. (2009). Differential effects of age on involuntary and voluntary autobiographical memory. *Psychology and Aging, 24,* 397–411. https://doi.org/10.1037/a0015785.

Schlagman, S., Kvavilashvili, L., and Schulz, J. (2007). Effects of age on involuntary autobiographical memories. In John H. Mace (ed.), *Involuntary Memory* (pp. 87–112). Malden, MA: Blackwell.

Schmeichel, B. J. (2007). Attention control, memory updating, and emotion regulation temporarily reduce the capacity for executive control. *Journal of Experimental Psychology: General, 136,* 241–255. https://doi.org/10.1037/0096-3445.136.2.241.

Seli, P., Smallwood, J., Cheyne, J. A., & Smilek, D. (2015). On the relation of mind wandering and ADHD symptomatology. *Psychonomic Bulletin and Review, 22,* 629–636. https://doi.org/10.3758/s13423-014-0793-0.

Semeijn EJ, Michielsen M, Comijs HC, Deeg DJ, Beekman AT, Kooij JJ. (2013). Criterion validity of an Attention Deficit Hyperactivity Disorder (ADHD) screening list for screening ADHD in older adults aged 60–94 years. *American Journal of Geriatric Psychiatry 21,* 631–635.

Semeijn, E. J., Korten, N. C. M., Comijs, H. C., Michielsen, M., Deeg, D. J. H., Beekman, A. T. F., & Kooij, J. J. S. (2015). No lower cognitive functioning in older adults with attention-deficit/hyperactivity disorder. *International psychogeriatrics, 27,* 1467. https://doi.org/10.1017/S1041610215000010.

Shaw, G. A., & Giambra, L. M. (1993). Task unrelated thoughts of college students diagnosed as hyperactive in childhood. *Developmental Neuropsychology, 9,* 17–30. https://doi.org/10.1080/87565649309540541.

Smallwood, J. M., Baracaia, S. F., Lowe, M., & Obonsawin, M. (2003). Task unrelated thought whilst encoding information. *Consciousness and Cognition, 12,* 452–484. https://doi.org/10.1016/S1053-8100(03)00018-7.

Smallwood, J., Obonsawin, M., & Reid, H. (2003). The effects of block duration and task demands on the experience of task unrelated thought. Imagination, *Cognition, and Personality, 22,* 13–31.

Stahl, C., Voss, A., Schmitz, F., Nuszbaum, M., Tüscher, O., Lieb, K., & Klauer, K. C. (2014). Behavioral components of impulsivity. *Journal of Experimental Psychology: General, 143,* 850–886. http://dx.doi.org/10.1037/a0033981.

Stawarczyk, D., Majerus, S., Maquet, P., & D'Argembeau, A. (2011). Neural correlates of ongoing conscious experience: both task-unrelatedness and stimulus-independence are related to default network activity. *PloS one, 6,* https://doi.org/10.1371/journal.pone.0016997.

Stout, D. M., Acheson, D. T., Moore, T. M., Gur, R. C., Baker, D. G., Geyer, M. A., Risbrough, V. B., & MRS Team (2018). Individual variation in working memory is associated with fear extinction performance. *Behaviour research and therapy, 102,* 52–59. https://doi.org/10.1016/j.brat.2018.01.002

Suddendorf, T., Addis, D. R., & Corballis, M. C. (2009). Mental time travel and the shaping of the human mind. *Philosophical Transactions of the Royal Society B: Biological Sciences, 364,* 1317-1324. https://doi.org/10.1098/rstb.2008.0301.

Vandierendonck, A. (2021). On the Utility of Integrated Speed-Accuracy Measures when Speed-Accuracy Trade-off is Present. Journal of Cognition, 4(1), 22. DOI: http://doi.org/10.5334/joc.154

Vannucci, M., & Chiorri, C. (2018). Individual differences in self-consciousness and mind wandering: Further evidence for a dissociation between spontaneous and deliberate mind wandering. *Personality and Individual Differences, 121,* 57-61. https://doi.org/10.1016/j.paid.2017.09.022.

Vannucci, M., Batool, I., Pelagatti, C., & Mazzoni, G. (2014). Modifying the frequency and characteristics of involuntary autobiographical memories. *PloS one, 9.* https://doi.org/10.1371/journal.pone.0089582.

Vannucci, M., Pelagatti, C., & Marchetti, I. (2017). Manipulating cues in mind wandering: Verbal cues affect the frequency and the temporal focus of mind wandering. Consciousness and *Cognition, 53,* 61-69. https://doi.org/10.1016/j.concog.2017.06.004.

Vannucci, M., Pelagatti, C., Hanczakowski, M., & Chiorri, C. (2019). Visual attentional load affects the frequency of involuntary autobiographical memories and their level of meta-awareness. *Memory & cognition, 47,* 117-129. https://doi.org/10.3758/s13421-018-0854-0.

Vannucci, M., Pelagatti, C., Hanczakowski, M., Mazzoni, G., & Paccani, C. R. (2015). Why are we not flooded by involuntary autobiographical memories? Few cues are more effective than many. *Psychological research, 79,* 1077-1085. https://doi.org/10.1007/s00426-014-0632-y.

Verwoerd, J., & Wessel, I. (2007). Distractibility and individual differences in the experience of involuntary memories. *Personality and Individual Differences, 42,* 325-334. https://doi.org/10.1016/j.paid.2006.07.014.

Verwoerd, J., Wessel, I., de Jong, P. J., Nieuwenhuis, M. M. W., & Huntjens, R. J. C. (2011). Pre-stressor interference control and intrusive memories. *Cognitive Therapy and Research*, *35*(2), 161–170. https://doi.org/http://dx.doi.org.ez.statsbiblioteket.dk:2048/10.1007/s10608-010-9335-x.

Warden, E. A., Plimpton, B., & Kvavilashvili, L. (2019). Absence of age effects on spontaneous past and future thinking in daily life. *Psychological Research, 83(4),* 727–746. https://doi.org/10.1007/s00426-018-1103-7.

Wessel, I., Overwijk, S., Verwoerd, J., & de Vrieze, N. (2008). Pre-stressor cognitive control is related to intrusive cognition of a stressful film. *Behaviour Research and Therapy*, *46*, 496–513. https://doi.org/10.1016/j.brat.2008.01.016.

Wheeler, M. A., Stuss, D. T., & Tulving, E. (1997). Toward a theory of episodic memory: the frontal lobes and autonoetic consciousness. *Psychological bulletin, 121,* 331. https://doi.org/10.1037/0033-2909.121.3.331.

Wodushek, T. R., & Neumann, C. S. (2003). Inhibitory capacity in adults with symptoms of Attention Deficit/Hyperactivity Disorder (ADHD). *Archives of Clinical Neuropsychology, 18,* 317–330. https://doi.org/10.1016/S0887-6177(02)00152-X.

Woltering, S., Liu, Z., Rokeach, A., & Tannock, R. (2013). Neurophysiological differences in inhibitory control between adults with ADHD and their peers. *Neuropsychologia, 51(10),* 1888-1895.

Young, S., Goodwin, E. J., Sedgwick, O., & Gudjonsson, G. H. (2013). The effectiveness of police custody assessments in identifying suspects with intellectual disabilities and attention deficit hyperactivity disorder. *BMC medicine, 11,* 248. https://doi.org/10.1186/1741-7015-11-248.

Yu, J. C., Chang, T. Y., & Yang, C. T. (2014). Individual differences in working memory capacity and workload capacity. *Frontiers in psychology, 5,* 1465. https://doi.org/10.3389/fpsyg.2014.01465

Table 1. Means and standard deviations for variables measuring mood, fatigue, concentration, motivation, and performance on the vigilance task as a function of condition (low, medium, high inhibitory control and ADHD spectrum).

	Groups							
	Low inhibitory control capacity		Medium inhibitory control capacity		High inhibitory control capacity		ADHD spectrum	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Mood								
PANAS: Positive affect 1 (before the task)	43.40[a]	10.24	43.48[b]	9.26	45.25[c]	11.35	46.38[d]	8.71
PANAS: Positive affect 2 (after the task)	39.25[a]	11.72	37.23[b]	10.61	35.27[c]	11.49	38.05[d]	12.34
PANAS: Negative affect 1 (before the task)	18.22	4.96	18.60	4.87	19.68	5.99	18.54	4.33
PANAS: Negative affect 2 (after the task)	16.97	3.75	17.43	4.97	18.00	3.40	17.62	3.17
Before the vigilance task								
Physical fatigue	3.28	1.20	2.98	1.37	3.20	1.36	3.08	1.52
Psychological fatigue	3.20	1.20	3.25	1.45	3.83	1.58	3.22	1.42
After the vigilance task								
Physical fatigue	3.30	1.52	3.03	1.39	3.78	1.55	3.35	1.70
Psychological fatigue	3.88	1.52	3.90	1.47	4.32	1.38	3.81	1.65
Concentration on the task (retrospection)	5.00	1.32	4.43	1.39	5.00	1.30	4.78	1.23
Importance of performing the task well (retrospection)	5.75	1.26	5.40	1.39	5.58	.93	5.43	1.44
Perceived difficulty of the task	2.53	1.58	2.28	1.43	2.65	1.33	2.92	1.59
How interesting was the task	3.40	1.41	2.95	1.36	3.30	1.83	3.43	1.71
How interfering were involuntary thoughts with the vigilance task	2.70[1]	1.44	2.57[2]	1.38	2.73[3]	1.28	3.38[1,2,3]	1.50
How much involuntary thoughts were being suppressed	2.46	1.52	3.15	1.79	3.00	1.70	3.05	1.65
How much verbal phrases were ignored	3.65	1.76	3.72	1.76	3.78	1.96	4.27	2.04
How much verbal phrases were interfering with the vigilance task	2.43	1.66	2.05	1.39	2.46	1.46	2.89	1.56
Concentration on the vertical lines	5.63	1.33	4.72	1.76	5.27	1.48	5.19	1.24
Concentration on verbal phrases	3.95	1.96	3.92	1.71	4.27	1.52	4.00	1.90
Performance on vigilance task								
Proportion of targets detected	.92	.11	.92	.14	.95	.09	.89	.15
Correct response time (in seconds)	.77	.15	.76	.21	.75	.13	.82	.22
Concentration rating	4.46	1.31	3.92	1.21	4.47	1.21	4.29	1.29

Note. All questions but PANAS were rated on 7-point scales (1 = low to 7 = high). Means with the same numerical subscripts (e.g.,[1]) are significantly different between columns. Means with the same letter subscripts (e.g.,[a]) are significantly different between rows.

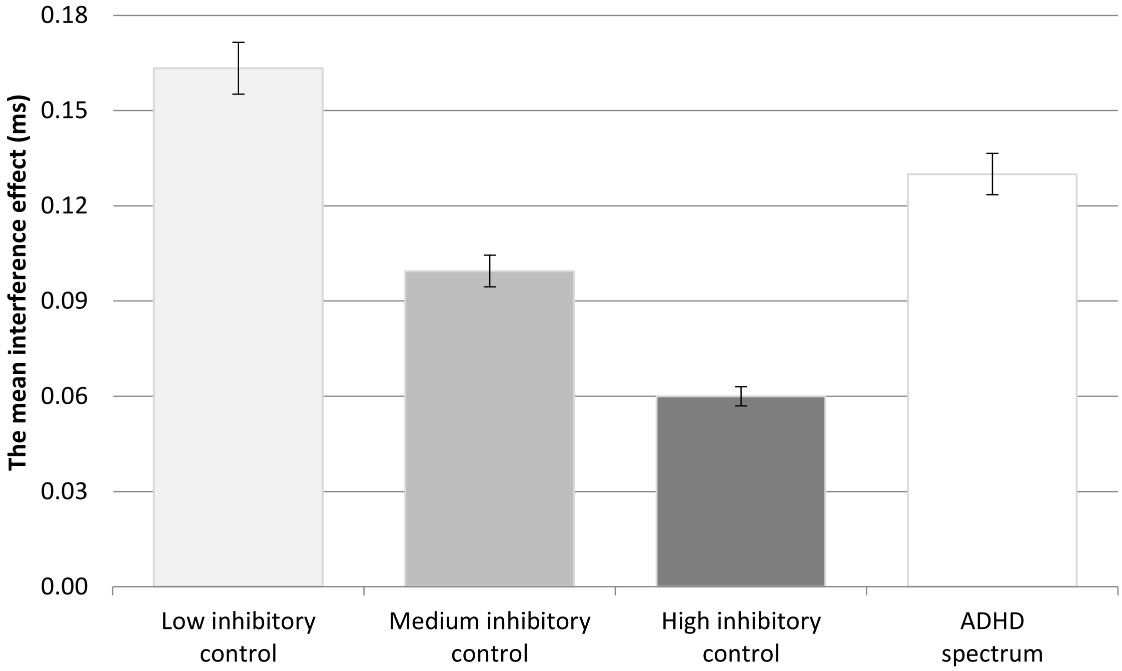
Table 2

Means and standard deviations for variables measuring number of involuntary thoughts, memories and future thoughts across groups.

	Group							
	Low inhibitory control capacity		Medium inhibitory control capacity		High inhibitory control capacity		ADHD spectrum	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Involuntary task-unrelated thoughts	9.90	3.61	8.40	4.03	8.65	4.73	8.57	4.30
Involuntary memories	3.85	2.88	3.70	2.85	3.98	3.83	3.51	3.81
Involuntary future oriented thoughts	3.13	2.32	2.75	2.36	2.65	2.63	2.24	1.83

Figure 1

The overall means of aggregated interference effect times in the laboratory-based Stroop-like task and in the Eriksen flanker task. Error bars indicate 95% confidence intervals for the comparison groups.



Note: The interference effect scores for each task were calculated as subtracting [RTs on congruent trials from RTs on incongruent trials] divided by RTs on congruent trials. The higher the Stroop effect, the weaker the individuals' inhibitory control capacity.

Declaration of interests

☒ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☐The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: