LUNDS UNIVERSITET

Department of Psychology

The effect of very light exercise on recognition memory in relation to attention ability

Mikael Hagström

Master´s thesis. 2015

Supervisor: Susanna Vestberg
Examiner: Elia Psouni

Acknowledgement

This thesis would not have been possible without the love and support of my wonderful wife. You never lost faith in me even though months turned into almost a year. My gratitude is beyond words. Of great help and importance was also the toy box I was allowed to borrow from my son. Without it the experiment would have been much harder to perform.

I have had much help from my supervisor, Susanna Vestberg, whom took me on in such short notice and for that I am grateful.

Abstract

Moderate exercise is deemed beneficial for cognition due to increase in dopamine concentrations in the basal ganglia. Auditory white noise is beneficial for cognition, mainly for those with lower attentional ability, i.e. for those having lower tonic dopamine concentrations. For individuals with higher attention ability white noise can have a negative effect. In this thesis it was examined whether very light exercise can function as a parallel to auditory white noise and, based on individual attention ability, have a beneficial effect on cognition and recognition memory. This is examined by testing recognition memory in two conditions: while walking and while being seated. Participants ($N = 26$) were recruited among university students and the general public, in two smaller towns in Sweden. Sitting was found to be more beneficial for recognition memory. This result was expected as the sample consisted of individuals with average to slightly above average attention ability. No other significant differences were found since the sample failed to include individuals with lower attention ability whom were the ones hypothesised to be most affected by the study. Further research with better sample is proposed as well as more attention demanding tasks to better identify a possible effect.

Keywords: attention, moderate brain arousal, exercise, basal ganglia, recognition memory

Introduction

The effect of exercise on cognition has long been studied with varying theoretical rationale. One of the first, and one that still is used today, is the theory of Davey (1973), that exercise would work as a stressor and thereby increase arousal. Davey reasoned, based on the arousal-performance interaction theory (Yerkes & Dodson, 1908) that there would be an inverted-U effect from acute exercise on cognitive performance. The inverted-U effect rationale is that a moderate intensity (in this case exercise) would yield better result than low or high intensity exercise. Coupling this with the fact that acute exercise increases the concentrations of the neurotransmitters dopamine (DA) and norepinephrine in the brain (Cooper, 1973), it has been argued that the increased concentrations would have, in terms of cognition, a “positive effect on speed of processing but possibly induce neural noise in areas of the brain involved in accuracy of processing” (McMorris, Sproule, Turner & Hale, 2011, p. 339).

Neural noise

When it comes to attention it would seem counterintuitive to add noise as a means of increasing attention. It has been shown that when it comes to sensory signal detection, as in discriminating something visually, tactilely or audibly (Moss, Ward, & Sannita, 2004), adding white noise (WN), i.e. random signals, is to a certain extent beneficial. This is due to a phenomenon known as stochastic resonance (SR). When WN is added to a stimulus, some of those signals will correspond to those of the target signal and thereby amplify the target signal, increasing the signal-to-noise ratio (SNR). This increase of SNR can actually bring an otherwise undetectable signal over the edge of detectability (Ward, Doesburg, Kitajo, MacLean & Roggeveen, 2006).

Stochastic resonance and signal-to-noise is limited by a non-linear function. This system follows a function of an inverted U. If the signal is too low the stimulus remains undetectable and if the signal is too high it blocks out the target stimulus (Moss, Ward & Sannita, 2004).

The effect of SR appears to be beneficial not just for picking up one specific signal but also for attention in general. Ward et al. (2006) have found that small amounts of added external noise increases neural activity, and thereby extracellular concentration of neurotransmitters – internal noise. This increases the probability that relevant neurons are activated and that whole neural circuits come in to synchrony and thereby increases the attention level. Auditory white noise was shown by Rausch, Bauch and Bunzeck (2014) in an fMRI experiment to have a beneficial “dopaminergic neuromodulation” effect and enhanced connectivity between the basal ganglia and the cortical regions.

A more detailed model for neural noise is explained in the Moderate Brain Arousal theory (MBA) (Sikström & Söderlund, 2007). Sikström and Söderlund (2007) reasons that adding external noise in the form of audible WN would increase internal, neural, noise to a moderate and beneficial level if presented at the optimal level. This optimal level is dependent on the individual pre-existing levels of phasic and tonic dopamine levels in, among other areas, the basal ganglia (BG) in each individual.

Phasic and tonic dopamine. Phasic DA, refers to the DA that is released upon reaching action potential from the presynaptic terminal into the synaptic cleft due to a relevant external stimulus. Tonic DA refers to low concentrations of DA that is freely available outside the synaptic cleft in the extracellular fluid. Tonic DA is continuous and regulates the reactivity of phasic DA. An increase in tonic DA activates the autoreceptors in the presynaptic cell and thereby works suppressing on the spike-dependent phasic DA while low levels of tonic DA increases phasic DA release (Grace, 1995).

Too high levels of tonic DA has been suggested to cause excessive stability in neural activity while too high levels of phasic DA is being suggested to cause neural instability and thereby result in cognitive symptoms like failure to sustain attention, distractibility and excessive flexibility (Bilder, Volavka, Lachman, & Grace, 2004). All these latter symptoms are associated with the neuropsychiatric disorder Attention Deficit/Hyperactive Disorder (ADHD). Methylphenidate hydrochloride (MPH) – a common substance in the treatment of specifically ADHD – is theorised to work by blocking the DA reuptake transporters and thereby increasing the available tonic DA (Krause, Krause, Dresel, Kung, & Tatsch, 2000). It has been found that MPH also directly enhances activation in BG (Coghill et al., 2014) even among healthy volunteers (Linssen, Sambeth, Vuurman & Reidel, 2014).

Basal Ganglia

The basal ganglia are a subcortical region that is highly involved in regulation of voluntary movement. It has among other things a key role as a feedback loop between cortex and thalamus that keeps movement smooth. But apart from this, activity in the BG is also highly correlated to activity in the prefrontal cortex and cognitive functioning dependent on this region (Middleton & Strick, 2000). In an experiment where the effect of distractors on attention was studied, Klingberg and McNab (2008) found that activity in BG was responsible for filtering out distractors that otherwise would compete for working memory capacity. Lavie (2005) showed that having a high enough perceptual load prevents distractions from interfering with attendance to task relevant stimulus. This could be argued to be due to increased arousal due to sensory input and that the increase of activity in BG due to SR would give better ability to filter out irrelevant signals and maintain focus on relevant stimulus due to neural synchrony.

Physical exercise has also been shown to be highly associated with increased mass and activation of the BG. Children who are more physically fit, and thereby have larger brain volume in this area, are superior with regard to cognitive control and memory when compared to their peers who are not as fit (Chaddock et al., 2012; Chaddock-Heyman, Hillman, Cohen & Kramer, 2014). In direct connection to intense physical exercise there is a positive effect on learning both with regard of intermediate and long-term retention. The increase of the catecholamines DA and epinephrine in BG are considered to be the cause of this (Winter et al., 2007).

It would appear that in the long run, regular physical exercise increases BG's volume (Chaddock et al., 2012) and this could be assumed to give a lasting effect on cognition as well. In the short term though, catecholamine concentration within the neuron has a half-life of between 8-12 hours (Eisenhofer, Kopin & Goldstein, 2004) while in the extracellular fluid, in the periphery, the half-life is only approximately 3 minutes (Dietrich, 2003; McMorris & Graydon, 2000). McMorris and Hale (2012) argued that it is the central concentrations that are most likely to have effect on cognition and therefore that performing tests of cognition after exercise is more relevant. According to the theory of MBA, tonic concentrations are the key and therefore it is of higher interest to study the effect on cognitive processes during the exercise than after exercise.

Attention

Attention can be defined in different ways, a comprehensive definition is put forth by Posner and Rothnart (2007) as "the regulating of various brain networks by attentional networks involved in maintaining the alert state, orienting, or regulation of conflict" (p. 2). Other ways to define attention or the lack thereof is by statements of behaviour like the inability to stay focused "during tasks or play activities", or fail to "give close attention to details or make careless mistakes", "does not seem to listen when spoken to directly" and similar statements as examples of criteria for ADHD according to the *Diagnostic and*

Statistical Manual of Mental Disorders (DSM) (American Psychiatric Association, DSM-5 Task Force, 2013).

Attention is critical for efficient encoding into memory. Being attentive to the task at hand helps preserve salient information that is crucial for successful retrieval of the information from memory (Christensen et al., 2012; Dubé, Payne, Sekuler & Rotello, 2013).

Helps, Bamford, Sonuga-Barke and Söderlund (2014) based their study on the MBA theory and tested super- normal- and sub-attentive children to see how different levels of WN affected them. They tested both non-executive functioning (non-EF, verbal episodic recall and delayed verbal recognition) and executive functioning (EF, visuo-spatial working memory and response inhibition). At a moderate level of WN, the super-attentive children's performance worsened in both non-EF and EF tasks while the sub-attentive group improved at EF tasks. The normal-attentive children were unaffected by the WN. Very little further effect was found when the stimulus shifted from medium to high levels of WN. This suggests that the main effect of external WN is in the lower to medium end.

In metaanalyses of the effect of different intensity of exercise on speed and accuracy of cognition, McMorris et al. (2011) found that moderate intensity exercise increased speed of processing, probably due to increased neurotransmitter concentration as an effect of increased arousal, but found no effect, or sometimes even a negative effect, on accuracy of working memory. Note that all these studies regarding the effect of exercise on cognition are based on the assumption that the baseline of attention is equal for all individuals.

The elusive inverted U effect between increased arousal and cognition

McMorris and Hale (2012) expect a non-linear function between increased arousal (i.e. in the central nervous system as an effect of external stimuli) and cognition, such that resembles an inverted U. However, several reviewers before them failed to find evidence for this (Brisswalter, Collardeau, & René, 2002; McMorris & Graydon, 2000; Tomporowski, 2003; Tomporowski & Ellis, 1986). McMorris and Hale (2012) found evidence of the U-function in speed of cognition but not in accuracy of WM, which they explain as probably due to "huge inter-individual variations" (McMorris & Hale, 2012, p. 341). Even when taking inter-individual variations into account, in form of the level of attention ability, this particular inverted U appears to be elusive. Helps et al. (2014) failed to find differences in effect in the higher end of the stimulus on the non-EF task. Since the stimulus used was auditory white noise, and the non-EF task was to remember spoken words, it might be that it became too difficult to hear the words for anything but a negative effect to occur. However, Kamijo et al.

(2009) performed a study where young and older adults were measured on cognitive functioning while performing acute aerobic exercise and they found a non-linear association (the inverted U) between the intensity of exercise and cognitive functioning and this association was valid for both young and old participants.

Very light exercise and cognition

Studies of physical activities effect on attention show positive effects for younger and older middle-aged adults (Winneke, Godde, Reuter, Vieluf & Voelcker-Rehage, 2012). Oppezzo & Schwartz (2014) noted though that a lot of research has been done on cognitive effects of physical activity but mainly focused on aerobic activity (running) rather than mild activity such as walking. What Oppezzo and Schwartz looked at instead was how walking affected creativity as a selective cognitive effect. Walking turned out to be an effective way to increase creativity, even if performed indoors on a treadmill. Hillman et al. (2009) studied the effect of walking on cognitive control of attention. Their findings support other findings showing that exercise, and even light exercise, can be beneficial for attention and cognitive health in general.

Aim of the thesis

To sum up it has been shown that attention is crucial for the sake of encoding relevant information and that exercise, even in lighter forms, can have a beneficial effect on cognition. This has most likely to do with heightened concentrations of DA in the BG, among other brain regions. It has also been shown that auditory WN increases the concentrations of tonic DA and that this is beneficial for individuals with lower attentional ability due to lower tonic DA concentrations but detrimental for individuals with higher attentional ability due to higher tonic DA. Tonic concentrations of DA are short-lived and this suggests that the main effect on concentration ought to be during the presence of stimulus, be it auditory WN or exercise.

In this thesis it is examined if very light exercise, in the shape of walking, can function in a similar way as auditory white noise which increases internal white noise, by activating the basal ganglia in a moderate way that promotes neural synchrony, and thereby increasing attention for those with lower attention ability compared with sitting down. Inter-individual differences in attentional ability will be taken into account and measurements of memory will be performed during the two conditions: light exercise and sitting down.

The aim of this thesis was to explore the impact of very light exercise on recognition memory. It was hypothesized that individuals with a low level of attention ability would benefit from very light exercise, that individuals with inter-mediate attention ability would be unaffected and that individuals with a high level of attention ability would be negatively affected. Furthermore, the impact of age, occupation and sex was analysed.

Method

Participants

The participants for this study were recruited from a swedish University and from the general population in a smaller swedish towns. Information regarding the study was delivered both through posters at the University area and through presentations during class and social gatherings. The participants were 26 in total and between the ages of 18-70 years with a median age of 27 years. The group was balanced regarding gender (53, 8% were men). Fifty percent of the participants were university students and the rest were either working or retired. Participation was voluntary and no compensation was offered. Participants were informed that all data would be handled confidentially and that they could quit the study whenever they wanted without any consequences.

Materials

The Strengths and Weaknesses of ADHD-symptoms and Normal-behaviours ratings scale. For self-evaluation of attention ability the participants filled in a version of the Strengths and Weaknesses of ADHD-symptoms and Normal-behaviours ratings scale (SWAN) (Swanson et al., 2007). The items in the SWAN scale are derived from the DSM-IV-TR diagnostic criterion for ADHD and the scale is very efficient at discrimination between ADHD’s three subtypes: Inattentive, Hyperactive and Combined (Arnett et al, 2013). The internal validity of the scale is high with mean Chronback’s alpha somewhere between .88 (Arnett et al, 2013) and .96 (Young, Levy, Martin & Hay, 2009). The Inattentive subscale on its own has a Chronback’s alpha of .94 (Young, Levy, Martin & Hay, 2009) The wording of the scale for this study was slightly altered so that the items were referred to the participants themselves instead of to a person being observed (see Appendix). This being the only change to the items, the validity of the scale should remain close to the same. Furthermore, since the main interest of this study is attention, only the items related to the subtype Inattentive (nine items in total) were used, thus giving a scale for attention/inattention only (SWANatt, see Appendix).

The SWAN scale has a 7 step grading: 3 “Far below average”, 2 “Below average”, 1 “Slightly below average”, 0 “Average”, -1 “Slightly above average”, -2 “Above average” and

-3 “Far above average”(Swanson et al., 2007). The SWANatt uses the same scoring giving a minimum mean score of 3 and maximum of -3 and a mean value was calculated for each participant.

Rey Auditory Verbal Learning Test. In order to more easily perform a cognitive test in group, an auditory recognition memory test, Rey Auditory Verbal Learning Test, was used. The words from a Swedish version of the Rey Auditory Verbal Learning Test (RAVLT) were used in order to measure recognition memory (Strauss, Sherman, & Spreen, 2006). Two parallel versions consisting of 25 words each were put together: 15 words from list A + 10 words from the original recognition test and 15 words from list B + 10 words from the original recognition test. The wordlists were pre-recorded using Audacity (Version 2.0.6; Mazzoni, 2014) and recorded on to a CD to ensure that the words were presented in the same way throughout the study. The words were read with one second intervals and a delay of 10 seconds before the list was repeated once. Onsite media systems where used to play the pre-recorded wordlists during the experiment. The recognition test in this study contained the 15 words presented earlier and an additional 10 words that were somehow related to the correct 15 words, e.g. crayon (false) being related to colour (correct). The recognition tests are presented in the Appendix.

For the scoring of the recognition tests, the raw scores of the correct and the “false alarm” answers for the sitting condition (SittCorr and SittErr) and the walking condition (WalkCorr and WalkErr) were used. The minimal scores were 0 and the maximal were 15 for the correct answers and 10 for false alarms. To take “false alarm” answers into account a d' was also calculated to get a compound score, sittDprime and walkDprime.

Procedure

The experiment was carried out in group sessions in a large room. The experiments consisted of two parts: Participants first answered a set of questions regarding background data and the SWAN questionnaire. Next the first wordlist was presented. The participants, while seated, listened to a list of words, which was presented twice. After a two minute pause the participants was asked to turn page in the handout and mark the words that they remembered from the list they just heard. In the second condition, participants were asked to listen to another list of words, presented twice, while walking at a leisure pace in the room. After 2 minutes’ pause, while still walking, they were asked to turn the page and mark the words they remembered in the second list of words. Participants were given 2 minutes to answer after each test.

Data Analysis

For assessment of the overall effect of condition the analysis was performed on the whole group while for the analyses of differences due to attention ability the participants were separated into subgroups based on their mean score on the SWANatt scale. Since Swanson et al. (2007) did not provide any directions regarding cut-off scores for the SWAN, the grouping was based on the mean result of the individual. The labels for the different levels where used to denote the groups.

The design of the experiment was set up so that the same participants were tested under two different conditions. Therefore a paired sample *t*-test was performed when all subjects were included in the analyses on the variables for correct answers (SittCorr, WalkCorr), false alarms (SittErr, WalkErr) and *d´*-values (sittDprime, walkDprime) from both conditions.

Due to the small sample size when the analyses were based on the groups, non-parametric analyses were used to examine if there was any relationship between attention ability and the performance on recognition memory (i.e. the above mentioned variables). A Wilcoxon Signed-ranks test was performed on each subgroup. To furthermore examine the impact of age a Mann-Whitney U test was used, while the impact of sex and occupation were examined using a χ^2 test of independence.

Results

The results of the word recognition tests can be seen in Table 1, for the sitting condition, and Table 2, for the walking condition. The SWANatt range was between 0,88 and -1,77 with a mean of -0,74 and *SD* = 0,70. A negative value here indicates “above average” attention ability.

Table 1
Scores of recognition memory from sitting condition

	Min	Max	*M*	*SD*
SittCorr	4	15	11,04	2,82
SittErr	0	3	1,35	1,09
sittDprime	-4,01	2,64	,00	1,65

Table 2

Scores of recognition memory from walking condition

	Min	Max	*M*	*SD*
WalkCorr	4	15	9,69	3,08
WalkErr	0	6	1,54	1,53
walkDprime	-3,14	2,40	,00	1,55

Is there an impact of very light exercise on recognition memory?

A paired-samples t-test was conducted to compare the participants' recognition memory during the seated and walking conditions. There was a significant difference between number of correct recognitions in the sitting (M = 11,04 , SD = 2,82, 95% CI [9,90 – 12,18]) vs. the walking (M = 9,69, SD = 3,08, 95% CI [8,45 – 10,94]) conditions; $t(25) = 2,52$, p = 0,019. The mean difference (1,35, 95% CI [0,25 – 2,45]) demonstrated a small effect size, d = 0.20. The differences regarding false alarms and the *d´*-scores were not significant (see Table 3).

Table 3

Paired Samples t-test between sitting and walking conditions (*N* = 26)

	Paired Differences							
				95% CI				Sig.
	M	*SD*	*SEM*	Lower	Upper	*t*	*df*	(2-tailed)
Sitting Correct score - Walking Correct score	1,35	2,73	,54	,25	2,45	2,52	25	,019
Sitting Error score - Walking Error score	-,19	1,86	,36	-,94	,56	-,53	25	,602
sittDprime – walkDprime	,00	1,90	,37	-,77	,77	,00	25	1,000

Is there a difference in impact on recognition memory during very light exercise as an effect of attention ability?

Given the relative small group of participants the separation into subgroups resulted in two subgroups, "Average" (M = -0.24, n = 15) and "Slightly above average" (M = -1.41, n = 11).

A Wilcoxon Signed-ranks test was performed for each subgroup to assess the relationship between attention ability (SWANatt) and the scores from the two different conditions (SittCorr, WalkCorr, SittErr, WalkErr, sittDprime, walkDprime). There were no significant differences between the scores under the different conditions for either subgroup (see Table 4).

Table 4
Wilcoxon Signed-rank test regarding the effect of attention ability on recognition memory during sitting vs. walking conditions

Attention ability		WalkCorr - SittCorr	WalkErr - SittErr	walkDprime - sittDprime
Average	Z	-1,59	-,22	-,17
	Asymp. Sig. (2-tailed)	,112	,823	,865
Slightly above average	Z	-1,57	-,26	-,27
	Asymp. Sig. (2-tailed)	,117	,796	,790

The impact of age, occupation or sex and attention ability

A Mann-Whitney U test was performed to see if the distribution of age differed across attention ability. The two groups did not differ significantly in age, $U(25) = 94,5$, $Z = 0,62$, n.s.

To see if occupation or sex differed over attention ability a χ^2 test of independence was performed. There was no significant relationship between either occupation and attention ability, $\chi^2(1) = 0,16$, $n = 26$, n.s., or sex and attention ability, $\chi^2(1) = 0,74$, $n = 26$, n.s.

How well does SWANatt relate to memory recognition performance

To see how well the self report of SWANatt related to memory recogniton under the two conditions a Pearson correlation test was performed. There was no significant correlation between SWANatt and SittCorr or SWANatt and WalkCorr. The correlation is actually close to zero for SittCorr, $r = ,076$, $n = 26$, $p = .714$, as well as for WalkCorr, $r = -,042$, $n = 26$, $p = ,839$.

Discussion

In this thesis it was examined whether light exercise, in the shape of walking, could function as a WN stimulus that would increase neural activity in a manner that affects recognition memory and that the effect would vary depending on individual attention abilities. Results showed that sitting still was in general more beneficial than walking when it came to recognition memory. Overall analyses were made before the participants were divided into subgroups, which showed that the participants correctly identified more words while sitting down than while walking. The effect size is rather small in this regard so one should not infer too much from this result, but a small ”nudge” can be enough to make a functional difference for the individual. Although this result stands at first glance in contrast with previous research (McMorris & Hale, 2012), this discrepancy can be explained with the distribution of the attention ability in the sample. The distribution of the attention ability was limited to only two of the most averaged subgroups with one leaning towards the higher end. Given the MBA theory regarding tonic DA concentrations (Sikström & Söderlund, 2007; Helps et al. 2014) it is the ones with lower attention ability who are most helped by white noise and that those with higher attention ability actually are negatively affected. Had the sample been normally distributed regarding attention ability then no difference between the conditions would have been expected when looking at the group as a whole since high and low attention ability would cancel each other out.

After dividing the participants into subgroups based on attention ability, the difference regarding recognition memory between the two conditions (sitting vs. walking) is no longer significant. As for demographics, none of the variables differed significantly between the subgroups. The hypothesis of a non-linear function between increased arousal and cognition was not confirmed.

Limitations

This thesis is limited by the rather small sample of participants, and thereby lacking in statistical power, and also the distribution of attention ability there within. A larger sample might have helped by giving more power to the analysis but a wider distribution of attention ability would be of even more interest. It was proposed in this thesis, that walking would increase tonic DA concentrations. Given the fact that those that are most likely to be helped by this are those with lower attentional ability, a university might not be the place to get the widest spread of sample in regard to attention ability. Although not all participants were recruited there, about half was. This in it self does not explain any of the results but none of the participants scored in the “slightly below average” category or higher. Anther limitation is that such a small sample doesn’t allow for parametric analyses. Non-parametric analyses were used since the attention ability was not normally distributed.

Using a self evaluation is always a risk. In this thesis the SWAN scale, that does have high relaibility according to Arnett et al. (2013) and Young, Levy, Martin and Hay (2009), was altered from evaluation of someone else to a self evaluation. There is a possibility that this shift altered the reliability of the test. Given the lack of correlation between SWANatt and the performance in the different conditions it should be considered if SWANatt is in this case a valid instrument for attention ability *but* it should also be considered if this might be due to that fact that people might not have an accurate grasp of their own attention ability. Furhter testing is required to assure the reliability of SWANatt as an self evaluation scale of attention ability.

The use of recognition memory test as a test of cognition was mainly due to practical reasons, where it was practical to administer a test verbally to a group and to be able to present the test the same way in both conditions. Recognition memory is easily tested but it is also limited. Recognition memory is a non-executive function of cognition. It might be of interest to test executive functions as well but the more complex the task, the more complex the administration of the test becomes.

The administration of test on a group of participants rather than on individuals appears to have been a relatively successful method. In hindsight it might have been more experimentally controlled if each participant had their own set of head speakers so that the sound did not differ as they moved towards and away from the speakers in the room. Another alternative that would have made the method more controlled but more resource demanding would have been to have all participants on treadmills instead of walking freely.

As for the test of demand of attention ability, in future research it might be of interest to use something like the *n*-back test (McElree, 2001), where the participants keep track of 1, 2 or 3 words back from the one being presented and at cue recall this specific word. This is a much more attention demanding task but one that might be hard to administer in group. The suggested head speakers might be helpful.

Future research

The hypothesis of this thesis was not confirmed. This is largely due to sample issues and the theory could still be valid. Further investigations into this area should make sure to collect their sample either in a matched manner – by perhaps recruiting from a group with known or even diagnosed attention difficulties and matching them to a control group, or getting a larger sample from a more dispersed population to make sure that the attentional ability is more representative in its distribution.

An aspect that might be of interest to consider in future research is if the participants regularly “take their problems for a walk”. If individuals already have a tendency to walk while pondering problems this might have an effect on cognition tests, disregarding attention ability, due to habit.

References

American Psychiatric Association. DSM-5 Task Force, & American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders: DSM-5*. Arlington, Va: American Psychiatric Association.

Arnett, A. B., Pennington, B. F., Friend, A., Willcutt, E. G., Byrne, B., Samuelsson, S., & Olson, R. K. (2013). The SWAN captures variance at the negative and positive ends of the ADHD symptom dimension. *Journal of Attention Disorders, 17*(2), 152-162.

Bilder, R. M., Volavka, J., Lachman, H. M., & Grace, A. A. (2004). The catechol-O-methyltransferase polymorphism: Relations to the tonic-phasic dopamine hypothesis and neuropsychiatric phenotypes. *Neuropsychopharmacology : Official Publication of the American College of Neuropsychopharmacology, 29*(11), 1943.

Brisswalter, J., Collardeau, M., & René, A. (2002). Effects of acute physical exercise characteristics on cognitive performance. *Sports Medicine, 32*(9), 555-566. doi:10.2165/00007256-200232090-00002

Chaddock, L., Erickson, K. I., Prakash, R. S., Voss, M. W., VanPatter, M., Pontifex, M. B., . . . Kramer, A. F. (2012). A functional MRI investigation of the association between childhood aerobic fitness and neurocognitive control. *Biological Psychology, 89*(1), 260-268. doi:10.1016/j.biopsycho.2011.10.017

Chaddock‐Heyman, L.; Hillman, C. H.; Cohen, N. J.; Kramer, A. F. (2014). III. The importance of physical activity and aerobic fitness for cognitive control and memory in children. *Monographs of the Society for Research in Child Development, 79*(4), 25-50. doi:10.1111/mono.12129

Christensen, T. A., Almryde, K. R., Fidler, L. J., Lockwood, J. L., Antonucci, S. M., & Plante, E. (2012). Modulating the focus of attention for spoken words at encoding affects frontoparietal activation for incidental verbal memory. *International Journal of Biomedical Imaging, 2012*, 579786. doi:10.1155/2012/579786

Coghill, D. R., Seth, S., Pedroso, S., Usala, T., Currie, J., & Gagliano, A. (2014). Effects of methylphenidate on cognitive functions in children and adolescents with attention-

Deficit/Hyperactivity disorder: Evidence from a systematic review and a meta-analysis. *Biological Psychiatry, 76*(8), 603-615. doi:http://dx.doi.org.db.ub.oru.se/10.1016/j.biopsych.2013.10.005

Cooper, C. (1973). Anatomical and physiological mechanisms of arousal, with special reference to the effects of exercise. *Ergonomics, 16*(5), 601-609.

Davey, C. P. (1973). Physical exertion and mental performance. *Ergonomics, 16*(5), 595.

Dietrich, A. (2003). Functional neuroanatomy of altered states of consciousness: The transient hypofrontality hypothesis. *Consciousness and Cognition, 12*(2), 231-256. doi:10.1016/S1053-8100(02)00046-6

Dubé, C., Payne, L., Sekuler, R., & Rotello, C. M. (2013). Paying attention to attention in recognition memory: Insights from models and electrophysiology. *Psychological Science, 24*(12), 2398-2408. doi:10.1177/0956797613492426

Eisenhofer, G., Kopin, I. J., & Goldstein, D. S. (2004). Catecholamine metabolism: A contemporary view with implications for physiology and medicine. *Pharmacological Reviews, 56*(3), 331.

Grace, A. A. (1995). The tonic/phasic model of dopamine system regulation: Its relevance for understanding how stimulant abuse can alter basal ganglia function. *Drug and Alcohol Dependence, 37*(2), 111-129. doi:10.1016/0376-8716(94)01066-T

Helps, S. K., Bamford, S., Sonuga-Barke, E. J. S., & Söderlund, G. B. W. (2014). Different effects of adding white noise on cognitive performance of sub-, normal and super-attentive school children. *PloS One, 9*(11), e112768. doi:10.1371/journal.pone.0112768

Hillman, C. H., Pontifex, M. B., Raine, L. B., Castelli, D. M., Hall, E. E., & Kramer, A. F. (2009). The effect of acute treadmill walking on cognitive control and academic achievement in preadolescent children. *Neuroscience, 159*(3), 1044-1054. doi:http://dx.doi.org.db.ub.oru.se/10.1016/j.neuroscience.2009.01.057

Kamijo, K., Hayashi, Y., Sakai, T., Yahiro, T., Tanaka, K., & Nishihira, Y. (2009). Acute effects of aerobic exercise on cognitive function in older adults. *Journals of Gerontology: Series B, 64B*(3), 356-363. doi:10.1093/geronb/gbp030

Klingberg, T., & McNab, F. (2008). Prefrontal cortex and basal ganglia control access to working memory. *Nature Neuroscience, 11*(1), 103-107. doi:10.1038/nn2024

Krause, J., Krause, K., Dresel, S. H., Kung, H. F., & Tatsch, K. (2000). Increased striatal dopamine transporter in adult patients with attention deficit hyperactivity disorder: Effects of methylphenidate as measured by single photon emission computed tomography. *Neuroscience Letters, 285*(2), 107-110. doi:10.1016/S0304-3940(00)01040-5

Lavie, N. (2005). Distracted and confused?: Selective attention under load. *Trends in Cognitive Sciences, 9*(2), 75-82. doi:10.1016/j.tics.2004.12.004

Linssen, A. M. W., Sambeth, A., Vuurman, E. F. P. M., & Riedel, W. J. (2014). Cognitive effects of methylphenidate and levodopa in healthy volunteers. *European Neuropsychopharmacology : The Journal of the European College of Neuropsychopharmacology, 24*(2), 200. doi:10.1016/j.euroneuro.2013.09.009

Mazzoni, D. (2014). *Audacity* (2.0.6 ed.). http://audacityteam.org/: Audacity Team.

McElree, B. (2001). Working memory and focal attention. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 27*(3), 817-835. doi:10.1037/0278-7393.27.3.817

McMorris, T., & Graydon, J. (2000). The effect of incremental exercise on cognitive performance. *International Journal of Sport Psychology, 31*(1), 66-81.

McMorris, T., & Hale, B. J. (2012). Differential effects of differing intensities of acute exercise on speed and accuracy of cognition: A meta-analytical investigation. *Brain and Cognition, 80*(3), 338. doi:10.1016/j.bandc.2012.09.001

McMorris, T., Sproule, J., Turner, A., & Hale, B. J. (2011). Acute, intermediate intensity exercise, and speed and accuracy in working memory tasks: A meta-analytical comparison of effects. *Physiology & Behavior, 102*(3), 421-428. doi:10.1016/j.physbeh.2010.12.007

Middleton, F. A., & Strick, P. L. (2000). Basal ganglia and cerebellar loops: Motor and cognitive circuits. *Brain Research Reviews, 31*(2), 236-250. doi:10.1016/S0165-0173(99)00040-5

Moss, F., Ward, L. M., & Sannita, W. G. (2004). Stochastic resonance and sensory information processing: A tutorial and review of application. *Clinical Neurophysiology, 115*(2), 267-281. doi: 10.1016/j.clinph.2003.09.014.

Oppezzo, M., & Schwartz, D. L. (2014). Give your ideas some legs: The positive effect of walking on creative thinking. *Journal of Experimental Psychology, Learning, Memory, and Cognition, 40*(4), 1142.

Posner, M. I., & Rothbart, M. K. (2007). Research on attention networks as a model for the integration of psychological science. *Annual Review of Psychology, 58*(1), 1-23. doi:10.1146/annurev.psych.58.110405.085516

Rausch, V. H., Bauch, E. M., & Bunzeck, N. (2014). White noise improves learning by modulating activity in dopaminergic midbrain regions and right superior temporal sulcus. *Journal of Cognitive Neuroscience, 26*(7), 1469.

Sikström, S., & Söderlund, G. (2007). Stimulus-dependent dopamine release in attention-deficit/hyperactivity disorder. *Psychological Review, 114*(4), 1047-1075. doi:10.1037/0033-295X.114.4.1047

Strauss, E., Sherman, E. M. S., & Spreen, O. (2006). *A Compendium of Neuropsychological Tests. Administration, Norms, and Commentary – third edition.* Oxford: Oxford University Press

Swanson, J. M., Schuck, S., Mann, M., Carlson, C., Hartman, K., Sergeant, J., . . . McCleary, R. (2007). Categorical and dimensional definitions and evaluations of ADHD: The SNAP and the SWAN rating scales. *Retrieved December 2007 from* http://www.ADHD.net.

Tomporowski, P. D. (2003). Effects of acute bouts of exercise on cognition. *Acta Psychologica, 112*(3), 297-324. doi:10.1016/S0001-6918(02)00134-8

Tomporowski, P. D., & Ellis, N. R. (1986). Effects of exercise on cognitive processes: A review. *Psychological Bulletin, 99*(3), 338-346. doi:10.1037/0033-2909.99.3.338

Ward, L. M., Doesburg, S. M., Kitajo, K., MacLean, S. E., & Roggeveen, A. B. (2006). Neural synchrony in stochastic resonance, attention, and consciousness. *Canadian Journal of Experimental Psychology/Revue Canadienne De Psychologie Expérimentale, 60*(4), 319-326. doi:10.1037/cjep2006029

Winneke, A. H., Godde, B., Reuter, E., Vieluf, S., & Voelcker-Rehage, C. (2012). The association between physical activity and attentional control in younger and older middle-aged adults: An ERP study. *GeroPsych: The Journal of Gerontopsychology and Geriatric Psychiatry, 25*(4), 207-221. doi:10.1024/1662-9647/a000072

Winter, B., Breitenstein, C., Mooren, F. C., Voelker, K., Fobker, M., Lechtermann, A., . . . Knecht, S. (2007). High impact running improves learning. *Neurobiology of Learning and Memory, 87*(4), 597-609. doi:http://dx.doi.org.db.ub.oru.se/10.1016/j.nlm.2006.11.003

Yerkes, R. M., & Dodson, J. D. (1908). The relation of strength of stimulus to the rapidity of habit formation. *Journal of Comparative Neurology and Psychology, 18*, 459-482.

Young, D. J., Levy, F., Martin, N. C., & Hay, D. A. (2009). Attention deficit hyperactivity disorder: A rasch analysis of the SWAN rating scale. *Child Psychiatry & Human Development, 40*(4), 543-559. doi:10.1007/s10578-009-0143-z

Appendix

Välkommen!

Jag heter Mikael Hagström och skriver min magisteruppsats i psykologi vid Lunds universitet. Studien handlar om huruvida lätt rörelse påverkar vår uppmärksamhet. Jag är väldigt tacksam för ditt deltagande och du är viktig för min studie!

Bläddra ej i häftet!

Ålder [ ]
Kön Man [ ] Kvinna [ ]
Studerande Ja [ ] Nej [ ]

The SWAN Rating Scale – self report version
Compared to your peers, how do you consider you do the following:

	far below avg.	Below	slightly below avg.	Avg.	slightly above avg.	Above	far above avg.
1. Give close attention to detail and avoid careless mistakes	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
2. Sustain attention on tasks or activities	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
3. Listen when spoken to directly	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
4. Follow through on instructions and finish school work or chores	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
5. Organize tasks and activities	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
6. Engage in tasks that require sustained mental effort	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
7. Keep track of things necessary for activities	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
8. Ignore extraneous stimuli	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
9. Remember daily activities	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
10. Sit still (control movement of hands or feet or control squirming)	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
11. Stay seated (when required by class rules or social conventions)	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
12. Modulate motor activity (inhibit inappropriate running or climbing)	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
13. Keep noise level reasonable to the occasion	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
14. Settle down and rest (control constant activity)	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
15. Modulate verbal activity (control excess talking)	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
16. Reflect on questions (control blurting out answers)	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
17. Await turn (stand in line and take turns)	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
18. Enter into conversations & activities without interrupting or intruding	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

Jag gör denna delen av testet: Gående [ ] Sittande [ ]

Ringa in de ord som fanns med i listan

Trumma	Nos	Krita	Fontän	Hatt
Ros	Gardin	Strumpa	Trädgård	Barn
Bonde	Hem	Måne	Flod	Katt
Kalkon	Klocka	Hus	Kaffe	Färg
Bror	Träd	Lada	Vatten	Skola

Jag gör denna delen av testet: Gående [ ] Sittande [ ]

Ringa in de ord som fanns med i listan

Skrivbord	Kyrka	Pistol	Bo	Berg
Lärare	Vakt	Väder	Glas	Hand
Båt	Fönster	Fågel	Ballong	Lamm
Blomma	Penna	Främling	Sko	Kola
Moln	Fisk	Handduk	Mus	Spis

Tack för din medverkan!