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A Critical Evaluation of Selective Attention Measures

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A CRITICAL EVALUATION OF SELECTIVE ATTENTION MEASURES

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ABSTRACT

Selective attention is comprised of two simultaneous processes—the inhibition of distractors and the focus of attention on target stimuli; yet, many existing selective attention measures only measure one aspect of selective attention. This leads to a high possibility of Type I errors as high interference control or high working memory capacity may be mistaken for high selective attention. This paper proposes several criteria for high construct validity and external validity in selective attention measures.

Concerning construct validity, the test *must* allow participants to exercise selective attention, adequately measure the level of attention to the distractor stimuli, and adequately measure level of attention to the target stimuli. Concerning external validity, tests *should* utilize multiple modalities of stimuli. Several existing measures of selective attention were evaluated using these criteria, and it was determined that the Stroop color-word task had low construct validity, the other existing measures had moderate construct validity, and the Ruff 2 & 7 test was found to have moderate external validity. Two selective attention measures are proposed however, which have high construct validity, though only moderate external validity. Further research should attempt to develop these and other tests, though multiple modalities of stimuli should be utilized.

Keywords: selective attention, interference control, working memory, inhibition

To all those with AD/HD—
Whether they struggle with it
or embrace it.

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CHAPTER 1

INTRODUCTION

This paper aims to critically evaluate the construct validity and, to some extent, the external validity of selective attention measures. There being many concepts within cognitive psychology often holding only small, yet extremely important distinctions, measurement of any singular concept can be very difficult. In an attempt to further highlight such distinctions between selective attention and other constructs that some selective attention measures have failed to capture, a brief description of a few similar constructs, the measurement of such constructs, and contrasts between such constructs and measurements will precede the evaluation of selective attention measures.

One reason many measures claiming to measure selective attention may not in fact measure selective attention is that the majority of these tests are not developed for the purpose of studying selective attention alone. Rather, most of these measures are interested in studying attention in a more general sense. The construct validity of individual aspects of attention, especially selective attention, was therefore given less attention and priority in such cases. This I believe to be a mistake, for reasons I will explain shortly.

The Diagnostic and Statistical Manual of Mental Disorders (5th ed.; *DSM-5*; American Psychiatric Association, 2013) defines Attention-Deficit/Hyperactivity

Disorder (AD/HD) as "A persistent pattern of inattention and/or hyperactivity that interferes with functioning or development" (American Psychiatric Association, 2013, p. 59) and divides AD/HD into three separate presentations or subtypes: combined presentation, predominantly inattentive presentation, and predominantly hyperactive/impulsive presentation. One diagnosed with a predominantly inattentive presentation of AD/HD (ADHD/IA) meets the inattention criterion, but not the hyperactivity-impulsivity criterion (American Psychiatric Association, 2013). One with a predominantly hyperactive/impulsive presentation of AD/HD (ADHD/HI) meets the criterion for hyperactivity-impulsivity, but does not meet the criterion for inattention (American Psychiatric Association, 2013). One with a combined presentation of AD/HD (ADHD/C) meets the criterion for *both* inattention and for hyperactivity-impulsivity (American Psychiatric Association, 2013).

In addition to these three AD/HD subtypes, research suggests that another subtype of AD/HD may exist within the predominantly inattentive subtype, distinguished by differences in Sluggish Cognitive Tempo (SCT) (McBurnett, Pfifner, & Frick, 2001; Carlson & Mann, 2002). Symptoms of SCT include:

> Daydreaming excessively; Trouble staying alert or awake in boring situations; Easily confused; Spacey or 'in a fog'…; Stares a lot; Lethargic…; Underactive…; Slow moving or sluggish; Doesn't seem to understand or process information as quickly or as accurately as others; Apathetic or withdrawn…; Slow to complete tasks…; Lacks initiative to complete work or effort fades quickly (Barkley, 2012, p. 6)

A 2001 study identified significant association between SCT and ADHD/IA, which was markedly different than the co-occurrence of SCT with ADHD/C or

ADHD/HI (McBurnett, Pfifner, & Frick, 2001). However, not all of those within the ADHD/IA subtype demonstrate significant symptoms of SCT (McBurnett, Pfifner, & Frick, 2001; Carlson & Mann, 2002). Within ADHD/IA, individuals accompanied by SCT and individuals unaccompanied by SCT "did not differ on attention or learning problems," but those with ADHD/IA accompanied by SCT shared many social and behavioral similarities distinct from unaccompanied ADHD/IA and other ADHD subtypes (Carlson & Mann, 2002). "Thus, SCT [was found to] identif[y] a more homogenous subgroup of ADHD/IA children" (Carlson & Mann, 2002, p. 123). This points to the possibility that the inattention seen in ADHD/IA with SCT may be caused by problems with different aspects of attention than the inattention seen in ADHD/C and unaccompanied ADHD/IA, and may be "a qualitatively different disorder of attention and cognitive processing…[therefore] what is known about the nature, causes, and management of ADHD may not apply to this subset of children" (Barkley, 2003, p. 79). Yet, it must be noted that there is little known about the causes of AD/HD or the AD/HD subtypes. The cause or causes of AD/HD are not known (Carlson & Mann, 2002), so it is plausible that *all* of the AD/HD subtypes constitute different disorders of attention with different causes.

By researching the relative ability levels in different constructs of attention—such as selective attention—for each subtype, including the hypothesized fourth subtype (ADHD/IA accompanied by SCT), we could greatly expand our knowledge on the mechanics of AD/HD and possible causes, determine if the hypothesized fourth subtype is in fact a disorder of a different aspect of attention than the rest of AD/HD, and determine if any subtype is a disorder of the same aspect of attention. Such knowledge

would allow for great improvements in the treatment of AD/HD, as knowing the root of the problem makes finding effective solutions easier. Measures with high construct validity are necessary, however, if research is to be useful. This is why it is important to ensure that the measures of the different constructs of attention have high construct validity. Here, selective attention measures specifically are evaluated to ensure that those used have high construct validity.

CHAPTER 2

CONTRASTING CONCEPTS

Selective Attention

Selective attention is a two-pronged process of attention, involving the focusing of attention and the inhibition of attention (Yiend, Mathews, & Cowan, 2005). During selective attention one is focusing their attention to the stimuli relevant to the task at hand, and inhibiting one's attention to irrelevant stimuli (See Appendix, Figure 1). Inhibition of one's attention to irrelevant stimuli is almost always, if not always, only partial, rather than a complete blocking of all attention paid towards the irrelevant stimuli. So, by definition, performance should suffer less for one with high selective attention than one with low selective attention in distracting environments.

Working Memory

Working memory (WM) refers to the processing, storage, and retrieval of information, simultaneously (Conway, Cowan, Bunting, Therriault, & Minkoff, 2002)—in essence, a cognitive juggling act. Working memory capacity (WMC) refers to the level of mental workload an individual can handle while continuing to maintain WM processes—analogous to an individual's juggling ability.

Theoretically, it is possible that the performance of individuals with high WMC would not suffer in distracting environments as much as those with low WMC.

Theoretically, one with low selective attention but high WMC, despite being unable to suppress attention to distractors, could still allocate enough attentional resources to the target stimuli or task (See Appendix, Figure 2). As already stated, the performance of those with high selective attention abilities, theoretically, should also suffer less than the performance of those with low selective attention abilities in distracting environments. The performance of one with high selective attention abilities, however, should suffer less in distracting environments for a different reason than for the low selective attention and high WMC individual. The performance of one with high selective attention abilities should decrease less in distracting environments due to an ability to suppress attention to the distractors in order to preserve a high level of attention to the target. One cannot, therefore, distinguish the high selective attention individual from the high WMC with low selective attention abilities individual based on how the presence of distractors affects their performance.

Working Memory Capacity Measurement. While the form of these measures may vary, each measure involves a processing and retrieval component (Conway et al., 2005). Generally, participants are given an attention-demanding task, such as a math problem, that they must complete quickly and which appears with an unrelated or unpredictable stimuli that they must store and later recall. The attention-demanding task comprises the processing component of the measure, which serves only to provide at least enough cognitive load to force the use of working memory processes. The retrieval component of the measure consists of the participant's recall of the unrelated or unpredictable stimuli.

WM tasks require the processing of all the stimuli, relevant and irrelevant, in order to induce high mental workload. In so doing, this disallows inhibitory processes, therefore disallowing the exercise of selective attention. For this reason, those with high selective attention abilities, but low WMC will perform as all other participants with low WMC perform on WM tests: poorly.

Researchers are able to manipulate the mental workload levels by changing the difficulty of the processing task (Conway et al., 2005). Performance accuracy scores for the processing task are used to assess whether or not participants paid adequate attention to the processing component, ensuring adequate mental workload. Participants with low performance accuracy scores for the processing component cannot be assumed to have paid adequate attention to the processing task and therefore cannot be assumed to be under adequate mental workload. The data for participants with low performance accuracy scores for the processing task is therefore discarded (Conway et al., 2005). The effect of the manipulation of cognitive load on working memory processes is observed in the corresponding changes in a participant's performance accuracy scores for the retrieval tasks. As mental workload increases, the performance accuracy for the retrieval component of the task will demonstrate a significant detrimental change for one with low WMC far sooner than it will for one with a high WMC.

Interference Control

Interference control refers to the suppression of internal or external distractors (Nigg, 2000). Interference control greatly resembles selective attention, as it resembles the inhibitory attentional process of the selective attention process. The difference is important to note. While one is necessarily demonstrating high interference control when

one demonstrates high selective attention, one does not necessarily demonstrate high selective attention every time one demonstrates high interference control (See Appendix, Figure 3). Selective attention involves the inhibition of irrelevant stimuli (i.e. interference control) *and* attention to relevant stimuli, simultaneously.

Interference Control Measurement. While it is unknown what the Stroop Color-Word task was originally intended to measure (Roybal, M., 2004), it is "[p]erhaps the most widely cited measure of interference control" (Nigg, 2000, p. 222). In the Stroop task, participants are presented with color words (e.g. red, blue, green) in a colored font (e.g. red, blue, green) that in some trials matches and in other trials does not match the color word. Trials in which the color word and font color match are congruent trials. Trials in which the font color is different from the color word are incongruent trials.

Participants must identify the color of the font as quickly as possible, ignoring the word itself. Accuracy and response times are recorded for each trial. Results from the congruent trials, trials where the color word and font color match, provide a baseline from which to compare the results from the incongruent trials, those trials where participants had to exercise interference control. Participants with typical levels of interference control have high accuracy scores and shorter response times for the congruent trials, and somewhat slower accuracy scores and longer response times for the incongruent trials. Participants with low interference control should demonstrate a larger difference in accuracy scores and response times between congruent and incongruent trials than participants with high interference control abilities.

CHAPTER 3

SELECTIVE ATTENTION MEASURES

Qualities of a Good Selective Attention Measure

Construct validity is "A term used to indicate that the test scores are to be interpreted as indicating the test taker's standing on the psychological construct measured by the test" (American Educational Research Association, American Psychological Association, and National Council on Measurement in Education, 1999, p.174). To better illustrate, imagine three tests, tests X, Y, and Z claiming to measure construct A and two participants: Abby, who has above average abilities in construct A, and Beau, who has below average abilities in construct A, but above average abilities in a separate construct, construct B, which shares some surface resemblances with construct A.

The results of test X claim that both Abby and Beau have below average abilities in construct A. Test X does not measure construct A, as it did not identify Abby's above average abilities in construct A. Therefore, test X has poor construct validity as a measure of construct A. The results of test Y claim that both Abby and Beau have above average abilities in construct A. While test Y may measure construct A, test Y does not measure construct A in such a way as to discriminate between construct A and the similar construct B. Therefore, test Y also has poor construct validity as a measure of construct A. The results of test Z correctly claim that Abby has above average abilities in construct

A and Beau has below average abilities in construct A. Test Z, therefore, has high construct validity as a measure of construct A, as it both accurately measures the construct it claims to measure, unlike test X, and it discriminates between construct A and construct B, unlike test Y.

A selective attention measure must meet three criteria to be considered to have high construct validity as a selective attention measure. These criteria, I have named Allowance, Distractor Processing Measurement, and Target Processing Measurement.

A measure fulfills the Allowance criterion if the measure provides conditions that allow for the participant to exercise selective attention in full, including both the inhibition of distractors and the focus of attention to the target(s) simultaneously. This is important, as before a test can measure selective attention, a test must allow for selective attention to occur. To meet the allowance criteria, there must be a target stimulus that the participant may focus on, and a distractor stimulus or stimuli that the participant may ignore. A measure either completely fulfills or completely fails to fulfill the Allowance criterion. If a selective attention measure fails to fulfill the Allowance criterion, the level of fulfillment of the other criteria is useless and irrelevant, as the construct validity as a selective attention measurement is poor.

Tasks such as the reading span task, to provide one example, do not fulfill the Allowance criterion. A reading span task is a WMC measure in which participants are presented with one sentence at a time, each followed by an unrelated word or letter, and must determine if the sentence is semantically or syntactically correct, and recall the unrelated word or letter 2 to 6 sentences later (Conway et al., 2005). In this task, participants completing the reading span task correctly cannot exercise selective attention

as they must focus on both the sentence and the unrelated word or letter, and are not supposed to ignore any stimuli within the reading span task.

A measure fulfills the Distractor Processing Measurement criterion if it measures the degree to which a participant inhibits processing of and attention to the distractor(s). Unlike the Allowance criterion, there are different levels of fulfillment for the Distractor Processing Measurement criterion. The more detailed the information on the degree to which the participant processed the distractor(s), the greater the Distractor Processing Measurement criterion is fulfilled.

Information on the depth at which participants processed the distractor(s) provides qualitative information on participants' attention to the distractor. Information on the frequency and duration with which participants attend to distractors provides a quantitative description of participants' attention to distractors. Information on the depth at which the distractor is processed is greater than information on the length of time or frequency with which one attends to the distractor in terms of Distractor Processing Measurement. Imagine that a participant attended to the distractor frequently and/or for long periods of time, yet only processed the distractor on a surface level. If one knew how frequently and/or how long the participant attended to the distractor, but did not know how shallow the processing level of the distractor was, one might wrongly suppose the participant was demonstrating a high level of attention to the distractor.

Some tests attempt to measure attention to the distractors indirectly by examining how the presence of qualitatively or qualitatively different levels of distractors affects the participant's level of attention to the target. In such measures, it is assumed that the degree to which attention to the target decreased in the trials of greater distraction

compared to the trials of lesser distraction is equivalent to the degree of increase in attention to the distractor(s) in the trials of greater distraction compared to the trials of lesser distraction. While this assumption is likely accurate, there is a possibility that it is not. If this assumption is correct, however, this form of distractor processing measurement still does not provide information on the depth of processing of the distractors, and is therefore fulfills the Distractor Processing Measurement criterion to a lesser extent than those that do provide information of the depth of processing.

A measure fulfills the Target Processing Measurement criterion if it measures the degree to which a participant attends to the target(s). Like the Distractor Processing Measurement criterion, there are different levels of fulfillment for this criterion as well, where more detailed the information on the degree to which the participant processed the target(s) means a greater level of fulfillment of this criterion. As with the Distractor Processing Measurement criterion, information of the depth at which the target was processed is superior to information on the frequency and duration with which the participant attends to the target.

The Target Processing Measurement and Distractor Processing Measurement criteria are necessary because they prevent the high likelihood of Type I errors. One may only be confirmed to be exercising high selective attention if it is known that the participant exercised *both* high attention to the target and low attention to the distractor. If one only measures participants' attention to the target, then one may wrongly assume that a participant showing high attention to the target is also paying little attention to the distractor(s), i.e. exercising high selective attention. However, the participant may in fact be attending greatly to both the distractor and the target, i.e. exercising *low* selective

attention and high working memory capacity (See Appendix, Figure 4). Similarly, if one only measures participants' attention to the distractor, then one may wrongly assume that a participant demonstrating low attention to the distractor(s) is also paying great attention to the target, i.e. exercising high selective attention. However, the participant may also be paying little attention to the target, i.e. *merely* exercising high interference control, and therefore *low* selective attention (See Appendix, Figure 5). Therefore, selective attention measurement tests must measure both the participant's level of attention to the target and level of attention to the distractor(s).

In addition to construct validity, external validity of the measures will also be evaluated. External validity refers to "how well the results of the study generalize to, or represent, people and contexts besides those in the study itself" (Morling, 2012, p. 66). External validity is important when applying research findings to the real world, such as utilizing knowledge about the functioning of selective attention in AD/HD individuals in certain contexts to develop techniques to help improve the functioning of selective attention in AD/HD individuals in similar contexts.

The external validity of a measure must be evaluated, in part, on a case-by-case basis; however, there is one general note about external validity for selective attention tasks that must be made. Most situations outside of the lab calling for the exercise of selective attention are not isolated to a single modality, with both the target and distractor stimuli being, for example, auditory stimuli. For this reason, in terms of external validity, the use of multiple modalities of stimuli is preferred—we will call this external validity criterion Stimuli Modality Diversity.

Visual Pursuit/Tracking Tasks

Visual pursuit, or visual tracking, tasks ask participants to track the movement of a target stimulus (often a dot) among other moving distractor stimuli, while cameras monitor their eye movements in relation to the path of the target stimuli on the screen. To do so, participants must practice visual selective attention, attending to the moving target and suppressing attention to the moving distractors. Monitoring of eye movements allows researchers to record when the participant is attending to the target and when the participant is attending to distractors.

Attention to the target and attention to the distractor are measured very similarly. Attention to the target may be measured by examining the length or lengths of time that the participant's eye movements match the path of the target stimulus without stray and the frequency with which the participant's eyes stray from the target. Attention to the distractor may be measured by examining the length or lengths of time that the participant's eye movements do not match the path of the target stimulus and the frequency with which the participant's eyes stray from the target. As discussed previously in the chapter, this form of measurement of target processing is useful, but not as accurate or detailed as measurements that provide the level at which the target was processed. For this reason, visual pursuit/tracking tasks should be said to fulfill the Target Processing Measurement and Distractor Processing Measurement criteria to a moderate degree.

The Allowance criterion is satisfied as participants are instructed to simultaneously attend to a target, the target dot, and suppress attention to the distractor dots. As visual pursuit/tracking tasks meet the Allowance criterion, moderately satisfy the target processing measurement criterion, and moderately satisfy the Distractor Processing

Measurement criterion, visual pursuit/tracking tasks should be considered to have moderate construct validity as a measure of selective attention.

As both distractor and target stimuli are visual stimuli, visual pursuit/tracking tasks do not fulfill the Stimuli Modality Diversity criterion. There are also few real world activities or situations resembling these tasks. Visual pursuit tasks could be said to resemble the tracking of a single ant in an ant farm, or the tracking of a person in a crowd, though these are not common activities. For these reasons, visual pursuit/tracking tasks should be considered to have low external validity.

Ruff 2 & 7 Selective Attention Test

The Ruff 2 & 7 Selective Attention Test is used to measure visual attention, sustained attention, and visual selective attention (Miller, n.d.). The test involves a series of 20 trials in which participants are told to cross out as many twos and sevens on the page as they can in 15 seconds (Miller, n.d.). The target stimuli, numbers 2 and 7, are hidden amongst 3 rows of numbers in the 'controlled search' trials, and hidden amongst 3 rows of letters in the 'automatic detection' trials (Miller, n.d.). Subject's speed score—the total number of targets identified—and subject's accuracy score—the percentage of targets identified—is calculated for the controlled search trials and the automatic detection trials for a selective attention score (MIller, n.d.), which is expressed as a "T-score… and a percentile rank" (Miller, n.d.).

Controlled search trials and the automatic detection trials present the same quantity of distractor stimuli with the target stimuli, but controlled search trials present a greater quality of distractor stimuli, as distractor stimuli are of the same type as the target stimuli. The controlled search trials thereby require significantly more attentional

inhibition than the automatic detection trials for selective attention in order to focus on the targets. This provides two levels of difficulty for the inhibition of distractors.

The Ruff 2 & 7selective attention test clearly meets the Allowance criterion—participants must focus on finding the targets while ignoring the distractors. Speed and accuracy scores provide quantitative information on the level of attention to the target, though not qualitative, such as tests measuring depth of processing of the target. The Ruff 2 & 7 selective attention test can be said therefore to fulfill the Target Processing Measurement criterion to a moderate degree. The test is only capable of measuring attention to the distractor indirectly, through consideration of how much the presence of greater quality distractors decreased attention to the target. The greater the difference between the response times and accuracy scores for the automatic detection trials and the response times and accuracy scores for the controlled search trials, the greater the level of attention to the distractor. As discussed earlier in the chapter, this indirect method of measurement leaves room for error and cannot provide information on the depth at which the distractor was processed, and for this the Ruff 2 & 7 selective attention test should be said to fulfill the Distractor Processing Measurement criterion to a moderate degree. In satisfying the Allowance criteria and fulfilling the Target Processing Measurement and Distractor Processing Measurement criteria to a moderate degree, the Ruff 2 & 7 Selective Attention Test can be said to have moderate construct validity as a selective attention measure.

This visual search of this test, especially in the controlled search trials, moderately resembles the common real world activity of skimming a text for a certain word or phrase. The distractor and target stimuli, however, are both of the same modality, visual,

rather than mixed modalities and therefore has low stimuli modality diversity. The Ruff 2 & 7 Selective Attention Test should therefore be considered to have moderate external validity.

Stroop Color-Word Task

The Stroop Color-Word task has been used as a selective attention measure (Lavie, Hirst, de Fockert, & Viding, 2004), however, it is unknown what construct it was originally intended to measure (Roybal, n.d.). At first glance, the Stroop task would appear to meet the Allowance criteria, as participants are able to exercise selective attention during the incongruent trials: where the participant attempts to attend to the target stimuli whilst inhibiting distractor processing.

However, because of the Stroop effect, for those who are literate, it is not as clear. The Stroop effect is the name for the phenomenon whereby people have great difficulty naming the color of the ink, rather than the name of the word, when the two do not match, because of the highly automatized process of reading, regardless of intention (Ashcraft & Radvansky, 2010). Participants can intend to inhibit the distractor (the word), yet the participants will process the word, regardless, because literate people are primed to first access the meaning of the word upon sight (Ashcraft & Radvansky, 2010, p. 138). The color of the ink, the target, is processed after the processing of the word, the distractor. One must suppress or inhibit one's automatic urge to respond based on the distractor, rather than the target—this is less selective attention and more behavioral inhibition. "Behavioral inhibition involves the (potentially intentional) control of overt behavior, such as resisting temptation, delay of gratification, motor inhibition, and impulse control" (Harnishfeger, 1995, p. 184). As the Stroop color-word task does not

satisfy the Allowance criterion, there is no need to consider whether or not the task satisfies the criteria of Target Processing Measurement or Distractor Processing Measurement. The Stroop color-word task has low construct validity.

In addition to low construct validity, the Stroop color-word task also has low external validity. Both the target and distractor stimuli are visual stimuli, and there are no common, real-world tasks resembling the Stroop task.

Flanker Tasks

In a flanker task, participants must respond quickly in each trial to the target stimulus located in the center of the screen and flanked by distractor stimuli. There are two types of trials: compatible trials, in which the target and distractor stimuli match, and incompatible trials, in which the target is different than the distractor stimuli. "In one version of the [flanker] task, participants are instructed to [quickly] respond to a central target letter flanked either by the same letters (e.g., *HHHHH;* compatible) or letters mapped to the competing response (e.g., *HHSHH;* incompatible)" (Redick, Heitz, & Engle, 2007, p. 129). As with the Ruff 2 & 7 Selective Attention test, experimenters record response times and accuracy scores (Redick, Heitz, & Engle, 2007). This task fulfills the Allowance criterion, as participants must exercise selective attention during incompatible tasks, responding to the target and not the flankers.

As with the Ruff 2 & 7 test, the degree to which the participant attends to the target can be determined by the speed and accuracy scores, and the degree to which the participant attends to the distractors is determined indirectly by comparing the differences in response times and accuracy across the two types of trials. Like the Ruff 2 & 7 test and for the same reasons, flanker tasks can be said to satisfy the Target Processing

Measurement and Distractor Processing Measurement criteria to a moderate degree, and, therefore, can be said to have moderate construct validity as a selective attention measure.

In regards to external validity, flanker tasks do not resemble many—if any—real world situations and the stimuli modality diversity is low as distractor and target stimuli are of the same modality. Flanker tasks therefore should be said to have low external validity.

Dichotic Listening Task

A dichotic listening task is a task in which subjects receive two separate auditory stimuli simultaneously, through separate ears (Sen, 1983). Such a task could be easily adapted for a selective attention measure with strong construct validity, as I will describe.

Researchers could tell subjects that they would be tested afterwards on one (the target) of the two stimuli, indicating the target stimuli beforehand and asking the subjects to pay great attention to the target for the test. Abiding subjects will attempt to attend to the target auditory stimulus and inhibit the distractor stimulus, i.e. exercise selective attention. This fulfills the Allowance criterion.

Afterwards, subjects would be tested on knowledge of both stimuli, testing the level of knowledge the subject holds about each stimulus (e.g. physical aspects, language, content, etc.). Results of this test would provide in-depth information on the depth at which the participant processed the distractor stimulus and the depth at which the participant processed the target stimulus. This would fulfill the Distractor Processing Measurement and Target Processing Measurement criteria. So, this proposed version of a

dichotic listening task fulfills all three criteria, offering high construct validity as a selective attention measure.

The task has only moderate external validity, however. This task greatly resembles selective attention in the real world, as people must often attempt to focus on one conversation and block out another close by. However, both the target and distractor stimuli are of the same modality.

Selective Shadowing Task

A selective shadowing task is a type of dichotic listening task in which the subject repeats aloud the target stimuli as they listen (called shadowing), which serves to reinforce the subject's attention to the target (Sen, 1983). This could also easily be adapted into a selective attention measure as well. If the selective shadowing task were carried out in the same manner as the dichotomous listening task described in the last section, differing only in that the participant shadowed the target stimulus. This would meet all three criteria, just as the dichotomous listening task did, making it a selective attention measure of high construct validity.

This selective shadowing task does not have high external validity, however. Like the other tasks, the distractor and target stimuli are of the same modality. Also, there are fewer instances in everyday life where one must repeat anything aloud as one hears it and another different vocal stimulus simultaneously. For this reason, this adaptation of selective shadowing tasks could be said to have low external validity.

CHAPTER 4

CONCLUSION

Of all the measures evaluated here, none were found to have both high construct validity and high external validity. None of the existing selective attention measures reviewed here were found to have high construct validity. It was determined that the Stroop Color-Word Task did not in fact measure selective attention at all, as the task did not provide circumstances to even allow for the exercise of selective attention by the participant. Visual pursuit/tracking tasks, the Ruff 2 & 7 Selective Attention Test, and flanker tasks were all found to have moderate construct validity. This was decided on the basis that all three allowed for the exercise of selective attention and measured attention to the target and attention to the distractors, though more accurate and detailed information about the level of attention to the target and to the distractors is possible, as demonstrated by my selective attention adaptations of dichotic listening tasks and selective shadowing tasks described in this paper.

The selective attention adaptations of dichotic listening tasks and selective shadowing tasks described in this paper were included to demonstrate that a greater level of target processing and distractor processing measurement was possible. Unlike visual pursuit/tracking tasks, the Ruff 2 & 7 Selective Attention Test, and flanker tasks, the selective shadowing and dichotic listening task adaptions provided information on the

depth at which the distractor was processed and the depth at which the target was processed. These dichotic listening and selective shadowing task adaptions fulfilled the Allowance criterion and highly satisfied the Distractor Processing Measurement and Target Processing Measurement criteria, and were thereby determined to have high construct validity.

None of the selective attention measures reviewed herein were determined to have high external validity as all used stimuli of only one modality and none had any great resemblance to common circumstances in which people exercise selective attention in the real world. Two tasks, the Ruff 2 & 7 Selective Attention Test and the selective attention adaptation of dichotic listening tasks, were determined to hold some resemblance to real world circumstances in which people exercise selective attention. These two tasks were said to have moderate external validity for this reason, while all other selective attention measures were determined to have low external validity.

Future directions in the study of selective attention should include a culling of so-called selective attention measures that fall short of the construct validity and external validity criteria presented here, and the use of such criteria to shape new selective attention measures such as those presented here. Further research should examine the construct validity of the measures of other constructs of attention, as future AD/HD research should focus on how the different subtypes of AD/HD and the probable fourth AD/HD subtype proposed by Carlson and Mann (2002) differ along many different constructs of attention. Such information could determine what aspect(s) of attention the deficit of attention is rooted in and determine whether or not that root is the same for all AD/HD subtypes and proposed subtypes. Knowledge of the source of the deficit would

allow for the development of more effective treatments or management strategies for those with AD/HD.

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APPENDIX

Figure 1. Illustrating Selective Attention: Level of Attention to Target/Distractor.

		Attention to Target	
		Low	**High**
Attention to Distractor	**Low**	**Low Selective Attention**	**High Selective Attention**
	High	**Low Selective Attention**	**Low Selective Attention**

Figure 2. Comparing and Contrasting WM and Selective Attention.

		Attention to Target	
		Low	**High**
Attention to Distractor	**Low**	**WM not Utilized + Low Selective Attention**	**WM not Utilized + High Selective Attention**
	High	**WM not Utilized + Low Selective Attention**	**High WMC + Low Selective Attention**

Figure 3. Comparing and Contrasting Interference Control and Selective Attention.

		Attention to Target	
		Low	**High**
Attention to Distractor	**Low**	**High Interference Control + Low Selective Attention**	**High Interference Control + High Selective Attention**
	High	**Low Interference Control + Low Selective Attention**	**Low Interference Control + Low Selective Attention**

Figure 4. Type I Error for Measurement of Attention to Target Alone.

		Attention to Target	
		Low	**High**
Selective Attention in Task	**Assumed**	**Low Selective Attention**	**High Selective Attention**
	Actual	**Low Selective Attention**	**High Selective Attention *OR* High WMC & Low Selective Attention**

Figure 5. Type I Error for Measurement of Attention to Distractor Alone.

		Selective Attention	
		Assumed	**Actual**
Attention to Distractor	**Low**	**High Selective Attention**	**High Selective Attention *OR* High Interference Control, but Low Selective Attention**
	High	**Low Selective Attention**	**Low Selective Attention**

Figure 6. Selective Attention Measures Evaluation Summary.

Test	Intended to Measure	Construct Validity	External Validity
Dichotic Listening Task Adaptation	Selective Attention	High	Moderate
Flanker Task	Selective Attention	Moderate	Low
Ruff 2 & 7 Selective Attention Test	Visual Selective Attention, Visual Attention, Sustained Attention	Moderate	Moderate
Selective Shadowing Task Adaption	Selective Attention	High	Low
Stroop Color-Word Task	Unknown	Low	Low
Visual Pursuit/Tracking Task	Visual Selective Attention	Moderate	Low

Figure 7. Comparison of Measures.

Used to Measure	Test	Description	Target Stimuli
Working Memory Capacity	Reading Span Task	Subjects read sentences, each followed by an unrelated word/letter, determine if the sentence is semantically or syntactically correct, and recall the unrelated word/letter after 2 to 6 sentence	-
Short Term Memory	Digit Span Task	Subjects are briefly presented with a string of numbers (whose length generally increases with each item), then required to recall this string shortly after the number string disappears.	-
Selective Attention	Ruff 2 & 7 Selective Attention Test	Consists of 20 15 second trials in which the participant must cross out as many 2s and 7s as they can, where the 2s and 7s appear among 3 rows of numbers in controlled search trials, and 3 rows of letters in automatic detection trials. Speed and accuracy scores are recorded for the two trial types.	The numbers 2 and 7
Selective Attention	Flanker Task	Participant is presented with a short line of letters, the center letter being the target, the flanking letters being the distractors. In compatible trials, center and flanking letters match (e.g. HHHHH). In incompatible trials, center and flaning letters do not match (e.g. HHSHH). Participant must respond quickly to the center letter. RT and accuracy are recorded and averaged for the two trial types.	Center Letter
Selective Attention	Visual Pursuit/ Tracking Task	A target dot moves on screen amongst other moving dots. Participants must follow the movement of the target and ignore the movement of distractors. A camera records eye movements.	Target Dot
Stroop Effect, Interference Control, Selective Attention	Stroop Color-Word Task	Color words are presented in a colored font. In congruent trials, the font color and color word match (e.g. red). In incongruent trials, the font color and color word are different (e.g. green). Participants are instructed to respond quickly according to the font color, not the color word. Accuracy and RT are recorded and averaged for the two types of trials.	Font Color
Selective Attention	Dichotic Listening Task - Wilson Selective Attention Adaption	Participant receives two separate auditory stimuli simultaneously through separate ears, and are told that they will be tested afterwards on their knowledge of the audio from one ear (e.g. right ear) designated by the experimenter. Afterwards, participant is tested on their knowledge of both auditory stimuli regarding such things as the physical aspects of the voice (e.g. male/female), the language, and the content.	Auditory Stimuli from designated Target Ear
Selective Attention	Selective Shadowing Task - Wilson Selective Attention Adaption	While the participant is exposed to two separate auditory stimuli simultaneously through separate ears, the participant repeats aloud the auditory stimuli from one ear (e.g. right ear) designated by the experimenter. Afterwards, participant is tested on their knowledge of both auditory stimuli regarding such things as the physical aspects of the voice (e.g. male/female), the language, and the content.	Auditory Stimuli from designated Target Ear

Distractor Stimuli	Allowance	Target Processing Mmt.	Distractor Processing Mmt.	Construct Validity	Stimuli Modality Types	Stimuli Modality Diversity	External Validity
-	No	-	-	-	Visual	Low	Low
-	No	-	-	-	Visual	Low	Low
Other numbers; letters	Yes	Moderate	Moderate	Moderate	Visual	Low	Moderate
Flanking Letters	Yes	Moderate	Moderate	Moderate	Visual	Low	Low
Other dots	Yes	Moderate	Moderate	Moderate	Visual	Low	Low
Color Word	No, due to interfer-ence by Stroop effect	-	-	Low	Visual	Low	Low
Audio stimuli from non-target ear	Yes	High	High	High	Auditory	Low	Moderate
Audio stimuli from non-target ear	Yes	High	High	High	Auditory	Low	Low