Through Your Spotlight : Individual Differences in Attentional Spotlight Size and the Correlation with Cognitive Functions and Personality Traits

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Abstract

Visual attention allows us to direct attention to a location in space and select information for perceptual processing. Attention operates like a beam of light that roams around our visual field and only stimuli within this beam of attention are processed. This beam of light is called the 'attentional spotlight' [40]. It has been explained by terms of global and local visual attention, i.e. processing with a possibly broader attentional spotlight and processing with a possibly narrower attentional spotlight. Previous studies showed an emphasis on finding a generally valid size and adaptability level. Investigating the differences between (groups of) individuals is important to understand cognitive anomalies and personality traits in these individuals. Therefore, this thesis addresses the possible differences in size and adaptability level of the attentional spotlight between (groups of) individuals. Firstly, by discussing the different models of spatial attention and how these have been studied. Secondly, by discussing the possible differences in attentional spotlight size and adaptability level between groups of individuals and the possible correlations with other cognitive functions and personality traits. Results show that differences in default attentional spotlight sizes do exist, but predominantly differences in the level of adaptability. Whether the difference in size and adaptability of the attentional spotlight results in the cognitive anomalies or the cognitive anomalies result in the difference in the attentional spotlight, differs between the groups of individuals.

***Keywords* - visual attention, spotlight, perception, individual, useful field of view**

Contents

Introduction

Visual spatial attention is crucial for enhanced visual perception. Spatial attention allows us to direct attention to a location in space and select information for perceptual processing. Stimuli located in the attended area are processed and stimuli outside this area are not. The selection process of information which is facilitated by our attention is essential for our brain, honestly because our brain is not able to process all accessible information at the same time. If the attentional mechanisms wouldn't select information to process, there would be a stimulus overload in our brain. Visual attention has most dominantly been studied using the attentional spotlight metaphor which was suggested by Posner and colleagues [40]. This metaphor suggests that attention operates like a beam of light that roams around our visual field and only stimuli within this beam of attention are processed. Therefore, our brain does not process all available information, but only the information located in our beam of attention is processed. This beam of light is called the 'attentional spotlight'. Later, adjustments on this beam of light were made which resulted in the zoom lens model in 1985 [12] [14], the gradient model in 1989 [28], and the multiple spotlight model in 1995 [1] [19] [27]. There is still no general consent on which of these models might represent all humans. These models will be mentioned in detail in chapter 2.

Spatial attention has been explained by terms of global and local visual attention. Global attention refers to processing the visual area with a possibly broader attentional spotlight, such that large features are processed more efficiently. Local attention refers to processing the visual area with a possibly narrower attentional spotlight, such that small features are processed more efficiently. The most commonly used methods to measure the size of the attentional spotlight are the Navon task and the spatial cueing task [36] [39]. The first part of this research will contain a description of the different spatial attention models and how these have been studied.

A lot of research in the field of spatial attention has been conducted using generic participants. Therefore, they do not represent the entire community. More insight into the possible differences in spatial attention between individuals will provide a stronger theoretical foundation for further research. Insight into the differences between individuals facilitates customization within all kinds of cognitive methods of research. It is vital to consider differences in visual spatial attention in understanding the different reactions of individuals during everyday tasks. If there are differences between individuals in their visual spatial attention, could these differences account for their specific cognitive anomalies? Or do the cognitive anomalies account for the difference in visual spatial attention? The elderly for example, it is commonly known that they need more time for everyday tasks and they lose accuracy. This might be a result of a deficit in their spatial attention. Specifically, the size of their spatial attention might be narrower or broader compared to others. This information could be used to improve existing research methods, for researchers to compare individuals and to fully understand where these possible differences arise. Insights into the origin of the cognitive differences might enhance mutual understanding between groups of individuals with specific cognitive anomalies and groups who fit the more standard approach. Most importantly, insight into the cognitive anomalies and their correlating visual attention would provide useful information to improve a more individualistic approach in research. The main aim of this thesis is to look at the possibility of individual differences in attentional spotlight size and their possible correlations with other cognitive functions and personality traits.

This leads us to the main question:

"To what extent do individual differences in spotlight size exist and are these differences correlated with other cognitive functions and personality traits?"

If there are differences in spotlight size between individuals, programs could use this information to make their software more applicable to individuals and make it less generic. One of these programs is made around the useful field of view (UFOV). UFOV represents the visual area from which a person can process information at a glance without eye of head movement, in other words, the capacity of the attentional spotlight. The UFOV paradigm is used to measure the width of participants spreading of spatial attention across an area. Therefore, it is the same kind of metaphor as the attentional spotlight or the zoom lens mentioned above. It is acknowledged that the UFOV shrinks as you get older. The UFOV is a great predictor of car crash frequency, the more shrinkage of the UFOV the higher the amount of car crashes in the last 5 years [3]. Practice through UFOV training programs or real-world training programs can enhance the width of the UFOV and therefore slow down the reduction of the UFOV in the elderly [4]. These training programs and assessments to enhance your UFOV are almost only used for the elderly in combination with traffic situations. The training programs could also be of use to enhance the UFOV in individuals who experience similar shrinkage as the elderly. The question remains if there are individual differences in the default size of the attentional spotlight size respectively UFOV. Possible groups of individuals who could benefit from the training programs are discussed.

The structure of this thesis will be as follows. Chapter 3 gives an introduction to spatial attentional models. Section 3.1 will explain the original spotlight metaphor suggested by Posner et al. (1980). Section 3.2 shows the three adjustments made on the spotlight metaphor (Posner, 1980) which resulted in the zoom lens model (Eriksen, 1986), the gradient model (LaBerge, 1989), and the multiple spotlight model (Hahn, 1998). Section 3.3 discusses the main methods that are being used to study visual spatial attention. Chapter 4 shows the differences in attentional spotlight size between groups of individuals. Section 4.1 explains the variance of the attentional spotlight size between individuals by showing examples and possible correlations. Chapter 5 discusses the findings in the sections above. The correlations between spotlight size and cognitive functions and personality traits combined with potential further research. It will give a more critical look at the methods being used in studying spatial attention. Chapter 6 ends with the conclusion.

Models of Spatial Attention

3.1 The Attentional Spotlight Model

Posner and colleagues described one of the first models of visual attention. This model describes the distribution of visual attention in our visual field [40]. This attentional spotlight states that visual attention operates like a spotlight that roams around our visual field and only stimuli within this beam of attention are processed. Because of this spotlight, attention will be drawn to a visual stimulus even if the focus is not located at the stimulus. Posner stated that stimuli in the focused location can be processed as well as in the peripheral field around it, only if the attentional spotlight covers this area. The attentional spotlight gives also more insight into why humans are able to process events taking place in the periphery. When the attentional spotlight is broad, the processing of events in the periphery is enhanced. The attentional spotlight does therefore explain disengaging, moving, and engaging of attention in a visual field. Posner stated that everyone has a default size of their attentional spotlight which can be adjusted depending on the task requirements [38].

3.2 Adjustments of the Attentional Spotlight

In the years following Posner's attentional spotlight, multiple researchers have made adjustments to his model of visual attention. In the subsequent sections, three of these models will be further addressed. Firstly, the zoom-lens model of Eriksen, James, and Yeh [12] [14]. Secondly, the gradient model of Laberge and Brown [28]. Finally, the multiple spotlight model of Kramer and Hahn [19] [27]. Figure 1 is a visual representation of these different models.

3.2.1 The Zoom Lens Model

Eriksen and James proposed a zoom-lens model in 1986 which is based on previous findings of Eriksen and Rohrbaugh (1970) about the similarity of the visual attentional system to a zoom lens [12] [13]. The zoom-lens model states that there is a trade-off relationship between the size of the visual field and the amount of stimuli which can be processed. Meaning, when the zoom lens covers a relatively wide surface of the visual field, differentiating between stimuli in the attended field becomes more difficult, which results in slower and less efficient processing. When the zoom lens covers a narrower surface of the visual field, it allows faster and more precise processing of stimuli within its beam.

3.2.2 The Gradient Model

LaBerge and Brown proposed a gradient model of attention in 1989 [28]. The gradient model states that the processing efficiency gradually decreases with the distance from the focused location. The processing of stimuli located at the focused location is enhanced and it decreases when the stimuli are located further away from the focused location. This model describes a rigid and flexible attentional gradient that can be modified on the demands of the task. As a result, attention is able to move away from the focused location.

3.2.3 The Multiple Spotlight Model

Kramer and Hahn proposed a multiple spotlight model in 1995 [27]. They found evidence for a division of attention among multiple non-contiguous locations in our visual field based on external stimuli. The division of attention is possible, but only under certain circumstances. The first circumstance states that the left stimulus has to be located in the left hemisphere and the right stimulus has to be located in the right hemisphere. The second circumstance states that there must be no grouping items between the two stimuli [19]. A prominent difference between the multiple spotlight model and the previously mentioned models is that there is no enhancement of processing in the focused location in the multiple spotlight model. Awh and Pashler also researched the ability of participants to split attention over multiple non-contiguous locations [1]. Their findings support the results of Kramer and Hahn.

Although there are multiple different models of visual attention, this thesis will focus mainly on the attentional spotlight. Which one of these models may be true, for the sake of simplicity, this thesis will continue with Posner's attentional spotlight. When Posner's attentional spotlight is addressed in this thesis, it will be shortened to the "attentional spotlight".

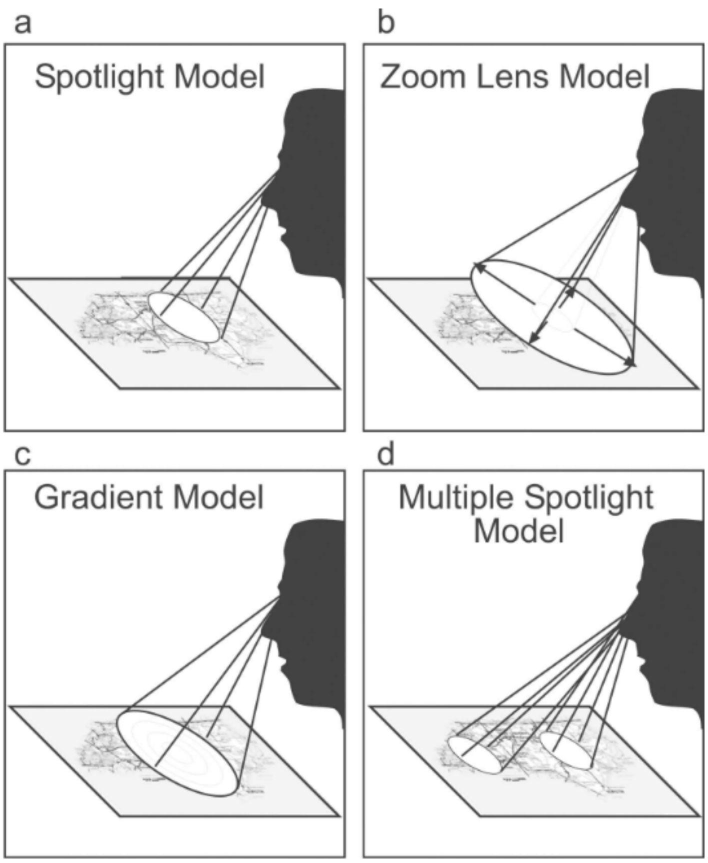

Fig. 1: A visual representation of The Spotlight (a), Zoom Lens (b), Gradient (c) and Multiple Spotlight (d). Image from R.E. Lloyd, *Attention on Maps*, Journal of the Brazilian Computer Society (2005), 28-57

3.3 Methods of Study

The most commonly used methods to study the attentional spotlight are the spatial cueing task and the Navon task. A less commonly used method is the Breadth-of-Attention task. The subsequent sections will further address these methods.

3.3.1 Spatial Cueing Task

The spatial cueing task (Posner cueing task) is often used for studying the orientation of visual spatial attention [39]. This task measures the reaction times to multiple target stimuli after a variety of cue conditions. Therefore, the effects of covert orienting of attention are studied. In this task, a target stimulus can appear either on the left or on the right of the fixation point. Before the target stimulus is presented, a cue is shown, this cue can either be a valid cue or an invalid cue. The trial is valid when the cue correctly indicates the location of the target stimulus and invalid when the cue incorrectly indicated the location of the target stimulus. Posner used 80% valid trails and 20% invalid trials during his initial study in 1980. The task provides a measure of attention between valid cues and invalid cues by manipulating the space between the cue and the stimulus. He concluded that the reaction time during valid trails was lower compared to the invalid trails. This resulted in his suggestion that when there is a cue, our visual attention is directed towards the cue and this enhances processing in this area. Posner linked this effect to the attentional spotlight moving in a visual area. When the cue appeared further away from the target stimulus, participants would take longer to engage, disengage and move to the location of the target stimulus compared to when the cue appeared closer to the target stimulus. If an individual detects a stimulus in the periphery faster than the control group, the individual has a broader attentional spotlight than the control group and vice versa.

3.3.2 Navon Task

The Navon task has been introduced by David Navon in 1977 [36]. The Navon task is a hierarchical letter-identification task in which the participants need to respond to figures in the shape of a letter which are made out of smaller letters. These figures have large features (the shape of a letter) and small features (smaller letters that make the shape of a large letter), hence the figures have global and local features. These global and local features can be congruent, the same big letter and smaller letters, or they can be incongruent, i.e. made out of different letters. Examples of these congruent and incongruent figures are shown in figure 2. Navon described three types of effects in his study. Global precedence is the effect in which the individual reaction to global targets is faster than the reaction to local targets. The interference effect states that the reaction time is slower in situations with incongruent stimuli and the inter-level interference effect describes that greater interference occurs on local feature trials than global feature trials.

There are two variations on the Navon task, the directed and the undirected version. In the directed version the attention of the participant is directed to either the global level or the local level of the figure. When the participant is asked to attend to the global feature of the figure, they will adjust the size of their attentional spotlight, zooming-out. If immediately after this they have to attend to a local level stimuli, it will be difficult because of the broader attentional spotlight which has to narrow down. When participants can switch fast and easily between the two levels, they are believed to have a flexible attentional spotlight. Therefore, the directed Navon task measures the efficiency of preparing and adjusting the attentional spotlight for a task. In the undirected version of the task, participants are not asked to attend to either the local or global level. They are asked to identify a set of targets from which one appears at either the local or global level of the upcoming figure. The relative response efficiency between the target being at the local level and the global level suggests the default attentional spotlight size. When responses to the global level are more efficient and more accurate than responses to the local level, the default size of the attentional spotlight must be broad. Vice versa, a more efficient response to stimuli at the local level suggests a default narrower attentional spotlight.

The directed version measures the level of adaptability of the size of the attentional spotlight and the undirected version measures the preference for local or global features and, therefore, the relative default size of the attentional spotlight.

Fig. 2: An example of the Navon figures used in the Navon task[36]. The left figure is congruent, local E and global E. The right figure is incongruent, local E global T.

3.3.3 Breadth-of-Attention Task

The Breadth-of-Attention task measures the maximum breadth of the attentional spotlight and has been introduced by Enns and Grigus (1985). It has been adjusted to the current version by Hütterman et al. (2014) [11] [22]. To study the maximum breadth, participants need to fixate their attention on the center of the screen. Two groups of shapes are presented along the horizontal axis, one group on the left and one on the right. After the shapes are presented, the participants have to answer two questions correctly, one about each group of shapes, this is used as the minimum criterion of accuracy. The groups of shapes are placed further and further away from the fixation point until one of the questions is answered incorrectly. The distance over which the groups of shapes are positioned provides the measure of the maximum breadth of the attentional spotlight. The sequence of events in a trial is shown in figure 3.

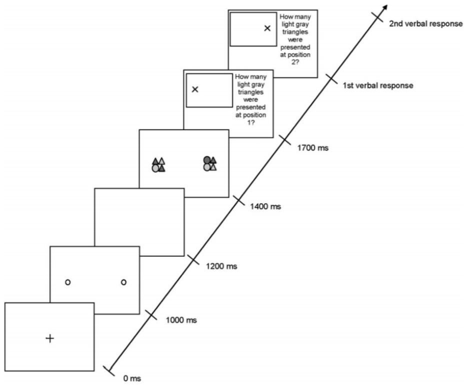

Fig. 3: An example of the Breadth-of-Attention task used in Hütterman et al. (2014) [22]

There is a fundamental difference in measurements between the spatial cueing task, the undirected Navon task, the directed Navon task, and the Breadth-of-Attention task. The spatial cueing task measures the width of the attentional spotlight through reaction times on peripheral stimuli. The Breadth-of-Attention measures the maximum width of the attentional spotlight through accuracy. The undirected Navon task measures the relative default width through the efficiency of the reaction. The directed Navon task measures the adaptability of the attentional spotlight through task switching between global and local features. The spatial cueing task, the undirected Navon task, and the Breadth-of-Attention task require participants to distribute their attention whereas the directed Navon task requires participants to focus their attention.

Individual Differences in Attentional Spotlight Size

4.1 Size variance

In order to describe possible individual differences in size and adaptability of the attentional spotlight, the subsequent sections will analyze different groups of individuals and correlations with cognitive function and personality traits. These groups of individuals represent a substantial part of our society, therefore they are discussed.

4.1.1 Age

Differences in cognitive functions between age groups have been studied for a long time. Due to age-related changes, there are differences in the performance, the approach, and the accuracy of multiple tasks. Enns and Girgus compared the adaptability of the attentional spotlight between two groups of children and a group of students, age means are respectively 7.6, 9.8, and 19.6 years, using a selective attention task [11]. The researchers concluded that young children are insufficient in zooming-in and relatively insufficient in zooming-out their attentional spotlight. The two groups of young children were also more affected by the irrelevant information, this occurred over a larger area of the visual field than the student group. Thus, children are especially less sufficient in zooming-in of their attentional spotlight, and therefore, have difficulty directing their attention to a specific area without getting distracted. Students on the other hand are more flexible in zooming-in and zooming-out their attentional spotlight when required.
Later, Greenwood and Parasuraman conducted experiments in which they compared the adaptability of visual attention between healthy young adults, adults, and elderly using a cueing task [17] [18]. Their findings suggested that younger adults are better able to control their attentional spotlight. In the absence of cues, the attentional spotlight of young adults stayed at the target stimulus size, resulting in easier detection of the target stimulus. They are less affected by the distractors and invalid cues. When asked, they can zoom-in or zoom-out depending on the task requirements and the previous cues. Healthy adults are slower in target stimulus recognition. An explanation is that healthy adults have an attentional spotlight which is less sufficient, i.e. they require more time, in zooming-in or zooming-out compared to young adults. When the target location is correctly cued and the cue has the same size as the target stimulus, the adults are still slower than the young adults. The attentional spotlight itself is also less focused, and therefore, they are more affected by distractors and invalid cues compared to young adults. Healthy elderly are slower in target stimulus recognition compared to the young adults and the adults, even when the target location is correctly cued and when the cue has the same small size as the target stimulus. They experienced great interference in the presence of distractors and invalid cues. A less focused attentional spotlight might explain the great interference. The elderly do not show a benefit from cues that are target stimulus size, which might indicate that they experience a deficit in the ability to zoom-in their attentional spotlight. Therefore, healthy elderly have a less focused attentional spotlight and trouble with efficiently narrowing it down when a task requires. Jefferies et al. (2005) investigated the dynamic effect involved in zooming-in and zooming-out of the attentional spotlight [23].

They compared a group of young adults and the elderly. Results showed that the elderly were two times slower in zooming-in the attentional spotlight. The initiation of zooming-in is thought to be slower because of a delay in the disengagement of the previously attended target.

Previously mentioned results suggest that young children have difficulties in zooming-in and zooming-out their attentional spotlight when a task requires that specific action. Student-aged individuals and young adults have a relatively focused attentional spotlight which they can easily zoom-in of zoom-out when asked. Adults are slowly losing the focus of their attentional spotlight and the ability to adjust the size depending on the task. The elderly lose the focus of their attentional spotlight in the periphery and they need more time to adjust, especially to zoom-in. Because elders need more time to adjust their attentional spotlight when they need to switch from one stimulus to the other, their response will take longer. As a result of the loss of focus, the outer area of the attentional spotlight loses most of the focus. The inner area maintains its focus. This results in a narrower field over which attention resources could be distributed. As mentioned in the introduction, the UFOV of the elderly shrinks. The loss of focus and the shrinkage of the UFOV are possibly linked. They have a narrower spotlight which is a result of the loss of focus in the outer areas. Therefore, the attentional spotlight of the elderly could be better explained through the gradient model of spatial attention. Young children react slower during everyday tasks and they often can't find their toys. This has probably something to do with their inflexible spotlight. When you want to find a toy, the first thing you do is find the room where you think it is, by zooming-out. To scan the room for the toy, you have to zoom-in. If both of these events do not work efficiently, you experience trouble finding the toy. Children might have an inflexible spotlight, therefore, they have trouble finding their toys. The elderly are known to have troubles in crowded places and their response to multiple events happening in the periphery is slower. This could be assigned to the time they need to adjust their attentional spotlight and the decline in focus or it could just be a part of cognitive decline that goes together with aging. The connection between cognitive decline and the attentional spotlight deficits in the elderly has to be researched further. One thing is certain, events that contain few distractors and do not demand fast responses are favorable for the elderly.

4.1.2 Cultural Background

Studies have been comparing the differences in perceptual processing between Western Caucasians (WC), East Asians (EA), and Himba individuals. Previous findings have shown that Westerners have a perceptual bias towards local information and East Asians towards global processing in scene perception [33].

McKone et al. used the Navon task to make a direct comparison of global and local processing between WC and EA that can be interpreted as relative differences in global and local attention [34]. This study showed a small (non-significant) local preference in WC versus a strong global preference in EA. Strong implies that EA were faster and more accurate than WC at global processing. Later, research had been conducted using the Navon task combined with electrophysiological signals that were recorded [29]. In the early stages of discrimination of features, EA showed greater sensitivity for global features and WC individuals showed a more neutral sensitivity at the same stage of processing. The preference for global features arises in a later processing stage in WC. EA make earlier and stronger discrimination for global figures. These findings are consistent with the findings of McKone et al.

A study of Kitayama et al. used a framed-line test (FLT) to investigate whether the hypothesis that EA are more focused on global information and WC more on local information, therefore ignoring global information [25]. During each trial, the participants are shown a square frame, within this frame a vertical line is printed. Later, another frame is shown, either the same size as before or a different size. The participants are asked to draw a vertical line in this frame which is identical to the first line, either in absolute length or proportionate to the square frame. The first option is the absolute task and the second the relative task. To investigate whether their hypothesis is right, they assumed that EA would perform better in the relative task (integrating global information) and that WC would perform better in the absolute task (ignoring global information). Results showed that EA were more accurate in the relative task (global task) and WC more accurate in the absolute task (local task). These findings are also consistent with the earlier mentioned studies.

Despite these earlier findings of the local perceptual bias of WC and the global perceptual bias of EA, which have been linked to local attention bias and global attention bias, Caparos et al. stated that the local and global perceptual biases must be distinguished from local and global selective attention [7]. In their research Caparos et al. compared a group of Himba participants and British participants using the Navon task. Earlier research showed that the Himba population experienced a local precedence bias compared to the British population [8]. If local processing bias is related to attention bias, then the Himba population should perform better at a local task. They would perform better through not getting distracted by global information and get more distracted by local information at a global task. Despite that, the Himba population did perform better on both the local and global tasks using the Navon figures. As a result, Caparos et al. suggested that the East Asians (from McKone et al.) do not experience difficulty in directing attention locally when the task demands. It does suggest that East Asians prefer global processing when they have a choice. The preference when having a choice theory could also explain the findings of Kitayama et al.

Previously mentioned findings suggest that EA have a stronger global precedence effect which results in their attentional spotlight being easier adjustable to large features, i.e. zooming-out. There might be a difference in the default attentional spotlight size between EA and WC, but this can not be concluded from earlier mentioned research that used focused attention.

The described differences between EA and WC cultures are thought to be explained by the more collectivist (global) EA cultures in comparison to the more individualistic (local) WC cultures. This theory could also explain the local precedence effect in the Himba population, an African tribe who takes care of their own and therefore being individualistic. Whether the difference in global and local processing biases is due to nurture and the environment in which someone grows up or it is set in genetics is not clear yet.

4.1.3 ASD

Individuals with Autism Spectrum Disorder (ASD) often show the ability to only attend to the details of a scene and not process the scene as a whole. A study by Robertson et al. investigated whether individuals with ASD have a sharper spatial gradient of attention than individuals without ASD [43]. This could potentially explain why individuals with ASD process a scene differently. Through a cueing paradigm combined with a visual acuity test they demonstrated that when the stimulus appeared further from the cue, the performance decreased in both ASD and the control group, this is an expected outcome. More interestingly, the performance of individuals with ASD was worse than the control group. Therefore, individuals with ASD showed an overall sharper gradient of visual attention versus the control group. The results in the ASD group showed that the sharpness of the attentional gradient was correlated to the severity of ASD. The sharp gradient of attention in ASD possibly signifies a narrow attentional spotlight.

Opposite results appeared in the study of Burack [6]. Two groups of participants, individ-

uals with ASD and individuals with no condition, had to identify a target that appeared in a central location, this was a forced-choice experiment. Individuals with ASD were more distracted by the presence of distractors than the control group, this suggests a broader attentional spotlight. During the experiment, the search window could differ in size. The default large window and a smaller window that appeared in the large window. When the search window was smaller (forcing the attentional spotlight to zoom-in), individuals with ASD were even faster in identifying the target stimulus, suggesting a broader attentional spotlight. Burack suggested that individuals with ASD have an overly broad attentional spotlight.
Other studies investigated the ability to adjust the size of the attentional spotlight to the attended area. Mann and Walker used a paradigm in which the participants had to guess which cross-hair was the longest, an adjusted version of an existing paradigm [30] [31]. In the experiment of Mann and Walker, the participants had to decide which of the two cross-hairs is the longest, horizontal cross-hair or vertical cross-hair. They found that the participants with ASH were less able to make a judgment about which cross-hair is the longest when the previously showed cross-hair was smaller than the cross-hair that had to be judged. Not only were they less able, but they were also slower than the control group. Mann and Walker argued that difficulties in zooming-out of the attentional spotlight could be a motive for the results of the study. Similar results were found in a Navon task experiment by Wang et al. [46]. They found a local bias in individuals with ASD and a reversed inter-level interference effect, in which there is more interference on global identity trails than on local identity trials. Findings suggested that individuals with ASD have difficulty zooming-out their attentional spotlight when the task requires. Rinehart et al. also found a deficit in shifting attention from local to global features, i.e. zooming-out, using the Navon task with numbers [42].
The question remains whether individuals with ASD have a narrow or broad attentional spotlight. Previously mentioned experiments do suggest that individuals with ASD do have a deficit in zooming-out. With the zooming-out deficit in mind, it would make more sense if individuals with ASD have a narrower attentional spotlight which they can't zoom-out efficiently.

The deficit in zooming-out together with a possible narrow attentional spotlight could be an explanation for some characteristics which are often seen in individuals with ASD. The sharper gradient of spatial attention, i.e. a narrower attentional spotlight, may take part in the enhancement of details in the visual attended area and might explain their 'tunnel-vision'. The deficit in zooming-out is a possible explanation of the ignorance of global features of a stimulus which might result in noticing only separate features instead of the scene as a whole. More insight into the distribution of attention in individuals with ASD could help with mapping the attentional neural circuit of the autistic brain. There is still no agreement on how this circuit differs from individuals without ASD, even though there are clear differences in attentional behaviour.

4.1.4 ADHD

Individuals with ADHD are often described as hyperactive, chaotic, and lacking attention. The term ADHD (Attention Deficit Hyperactivity Disorder) already indicates that there is a deficit in attention. Shalev and Tsal concluded by performing a Flanker Task that children with ADHD have difficulties in ignoring distracting information and restricting their attention to a bounded spatial area [44]. Therefore, they suggested that individuals with ASD have difficulty with zooming-in.
Even within the group of individuals with ADHD, there are different types of behavior. Three types of attentional deficits are defined [2]. The inattentive type (ADHD-I), the hyperactive type (ADHD-H), and the combined type (ADHD-C). The inattentive

type is characterized by difficulties remaining focused, overlooking details, being dreamy throughout the day, and difficulty organizing tasks. Opposite to the inattentive type, the hyperactive type is characterized by being restless and therefore always ‘energized’, impulsive, and uncomfortable when it is appropriate to be calm. The combined type is a combination of the characterizations of the inattentive and the hyperactive type.
Considering these different types, Heidbreder hypothesized that the size of the attentional spotlight must differ between the different types of ADHD [20]. Therefore, she suggested that the ADHD-I type might have a narrower attentional spotlight. Individuals with the inattentive type fail to detect stimuli outside of their attentional focus, therefore they do not have access to all information presented. The characterizations associated to ADHD-I do explain the constant missing of certain information and overlooking details. The ADHD-H and ADHD-C type might have a broader attentional spotlight. Individuals with the hyperactive type have been thought to be prone to a stimulus overload, because of their broad attentional spotlight. Too much information at the same time and not being able to focus on the necessary information results in wrongly selecting information in their visual field.
Song and Hakoda investigated the hypothesis which connects ADHD-I type individuals to a narrow attentional spotlight [45]. They used two versions of the Navon task, the directed Navon task and the undirected Navon task. In both cases, individuals with ADHD-I distributed their attention more locally and there was a local precedence effect. In the undirected Navon task, individuals with ADHD-I distributed their attention faster to the local features compared to the control group. In the directed Navon task, individuals with ADHD-I again showed local precedence. They were being distracted by local information during the global directed task (local interference) but were not distracted by global information during the local directed task (global interference). Findings suggest a narrow attentional spotlight combined with a deficit in zooming-out in individuals with ADHD-I.
Kalanthroff et al. used the directed Navon task to measure the adaptability of the attentional spotlight between two groups, a group of ADHD participants (predominantly ADHD-I type) and a control group [24]. The control group showed global precedence as expected from Navon’s original paper. The ADHD participants, on the other hand, did not show global precedence nor local precedence. This could results from a global processing deficit in adults with ADHD. Dissimilar from the results from Song and Hakoda, who did not only find a global processing deficit but also a local precedence deficit. A possible explanation might be the difference in population, where Song and Hakoda used children, and Kalanthroff et al. used adults. Symptoms of ADHD change over time [32]. This could account for the differences in results between the group of children and the group of adults. Individuals with ADHD experience low levels of alertness. An experiment investigated the connection between levels of alertness and local or global processing biases [21]. This experiment used an adjusted directed Navon task. Arrows were used instead of letters in combination with a warning signal. Results showed that high levels of alertness are connected to an enhanced global processing bias. The low level of alertness could explain the deficit in global processing.

The personality traits of the different types of ADHD can be explained by the size of their attentional spotlight. Individuals with ADHD are often very easily distracted, but the reason why differs between the different sub-types. Individuals with the ADHD-I sub-type are often distracted because they lose attention for what they are doing because of the missing of important information. Individuals with the ADHD-H and ADHD-C types are often distracted because they process too much irrelevant information located in the periphery. Individuals with ADHD-I are also often more susceptible to developing depression or anxiety. They often have a less complicated and therefore a more inactive social life compared to individuals with ADHD-H and AHDH-C. Individuals with ADHD-H and ADHD-C are more likely to become aggressive and therefore more likely to get into trouble [5]. Further research into the differences in attentional spotlight size and adaptability level between the sub-types and age-categories of ADHD is necessary for therapy at individual level.

4.1.5 Dyslexia

The dominant view about the origin of dyslexia states that there is a deficit in phonological processing. This, however, does not explain all differences in cognitive functioning in dyslexia and therefore, researchers have been trying to explain it in terms of attentional orienting and attentional selection.

Facoetti et al. (2000) conducted two experiments in which they analyzed the distribution of processing resources inside and outside the focus of attention and the distribution of processing resources in unfocused attention [16]. In the first experiment, the participants (a group of dyslectic children and non-dyslectic children) had to detect a white dot projected at different distances from the focus of attention while remaining focused at the center. The further the white dot was away from the focus of attention, the longer it would take to be detected. This was the case for non-dyslectic children. Dyslectic children did not show a reduced detection speed. Therefore, they have a more diffused distribution of attention in the visual field. This indicates that individuals with dyslexia might have a broader attentional spotlight than individuals without dyslexia. In the second experiment, the participants had to distribute their attention to find a stimulus between a variable number of distractors. With the increase of distractors, the reaction time of non-dyslectic children increased. This was not the case for dyslectic children. Dyslectic children have difficulty in zooming-in the attentional spotlight and therefore they can distribute their attention better compared to normal children. Dyslectic children might be better at zooming-out their attentional spotlight because of the deficit in zooming-in their attentional spotlight.

Facoetti and Molteni (2001) conducted almost the same experiment as experiment 1 mentioned above [15]. Instead of the white dot appearing anywhere surrounding the focus of attention, this time the white dot only appeared along the horizontal axis, either on the left or right. The further the white dot was away from the focus of attention, the longer it would take to be detected. This was again the case for non-dyslectic children. There were no differences in the stimulus appearing on the left or right side of the visual field. Dyslectic children did also show a slower reaction time when the stimulus appeared further away, but only on the left side of the visual field. This effect was not present in the right visual field, suggesting an attentional deficit in the right parietal cortex. Thus, the attentional spotlight of dyslectic children might be broader on the right side of the visual field.

A study by Moores et al. (2015) used an experiment based on experiment 1 mentioned above [35]. Their results were comparable to the earlier results, nevertheless, they interpreted the results differently. Moore et al. suggested that individuals with dyslexia have a weaker, i.e. less focused, attentional spotlight instead of a broader attentional spotlight. This would explain why individuals with dyslexia are not more accurate when the stimulus appears in the central area.

All of the previously mentioned experiments incorporated neither letters nor other complex stimuli, because of this, the phonological deficits are not able to account for the results. Whether individuals with dyslexia have a broader attentional spotlight combined with a deficit in zooming-in, or they have a less focused attentional spotlight, it influences their reading skills. When reading, it is desirable to focus on detail, to direct attention to letters and words. This way, readers can process relevant information and inhibit the processing of irrelevant information. If the attentional spotlight is indeed less focused, it could result in the processing of irrelevant letters surrounding the word that needs to be read. If the spacing between letters and words in a sentence is expanded, the reading ability of individuals with dyslexia increases. On the other hand, the whole word reading was affected negatively [37]. Slower reading and a lower accuracy rate may be the result of a broader or less focused attentional spotlight or a deficit in zooming-in the attentional spotlight.

4.1.6 Creativity

Creativity as a trait is often described as being 'open-minded' or not having 'tunnel-vision'. Earlier, the 'tunnel-vision' had been connected to the behaviour of individuals with ASD, and they have a deficit in zooming-out with a possible narrow attentional spotlight. Thus, when an individual is very creative, their attentional spotlight might be more flexible in zooming-out or be broader in default size.
Zmigrod et al. (2015) used the Navon task to investigate the local and global preferences of creative and less creative participants [48]. The level of creativity was measured using convergent/divergent thinking tasks and a fluid intelligence task. Results suggested that individuals who had to attend the global figure and thereby, did not get distracted by the local figures were more creative than individuals who did get distracted by the local figures. They suggested that creative individuals are more flexible and efficient in zooming-out their attentional spotlight. Identical results were found in Razumnikova and Volf (2015) using the Navon task, where the results suggested that figurative creativity is linked to more global processing [41]. More global processing itself is linked to an attentional spotlight that prefers to zoom-out.
Zabelina et al. (2016) compared two measures of creativity: divergent thinking and real-world creativity (artistic) and their selective attention mechanisms [47]. Using the Navon task, they showed that high divergent thinkers were more flexible in allocating attention between local and global features compared to low divergent thinkers. Therefore, high divergent thinkers can adjust their attention more efficiently when a task requires. Resulting in quick switches between cues, stimuli, and interfering distractors. They have a flexible attentional spotlight, that is able to zoom-in and zoom-out. Real-world creative individuals on the other hand were more affected by interference from distractors at the uncued level during incongruent trials. Real-world creative individuals were quicker when the stimulus information of the uncued level was congruent. Interfering information was more affecting real-world creative individuals than it affected less creative individuals. Less creative individuals are less efficient in adjusting their attention to local or global features. Zabelina et al. suggested that real-world creative individuals make more use of their cognitive control to use the attention needed. Creative people are often described as chaotic. High divergent thinkers switch very fast from stimulus to stimulus and also switch easily between local and global features, the fast switching can be seen as being chaotic. Interfering information causes real-world creative individuals to get distracted. The interference of information that is not relevant for others can also be seen as chaotic.

If individuals with a high creativity level are indeed able to adjust their attention spotlight easily, it could contribute to more cognitive flexibility when searching for new solutions in problem-solving thinking tasks but also in real life. Being creative, thinking about creative solutions for problems is linked to triggering a broader attentional spotlight. On the other hand, analytic thinking tasks, which demands less creativity are linked to triggering a narrower attentional spotlight [26].

4.1.7 Sports

To investigate a certain difference in the size of the attentional spotlight between physically active and non-physically active adolescents, Cereatti et al. used an adjusted directed Navon task [9]. They found that physically active adolescents were more capable of zooming-in and zooming-out, compared to non-physically active adolescents. Later Hütterman et al. performed an experiment in which they, like Cereatti et al., compared expert athletes and beginner athletes [22]. Previously mentioned research investigated the adaptability of the attentional spotlight, this research investigated the size of the attentional spotlight. Hütterman et al. used the Breadth-of-Attention task, their findings show that the attentional spotlight of expert athletes had a 25% greater maximum breadth. Thus, individuals who are more physically active, and fit the description of an expert athlete have a broader attentional spotlight. They are also more flexible in zooming-in or zooming-out compared to non-physically active beginner athletes.

So far, differences in attentional spotlight size have been noticed in the attentional spotlight being broad or narrow in the shape of a circle. Hütterman et al. also looked at differences in attentional spotlight shape in different sport disciplines. Results showed that experts in vertically oriented sports, e.g. volleyball, have a slightly more vertical shaped attentional spotlight and experts in horizontally oriented sports, e.g. soccer, have a slightly more horizontal shaped attentional spotlight.

Two main views can explain the size and adaptability seen in expert athletes. First, to become an expert in a certain sport, the athlete must be able to adapt their attentional spotlight as optimal to whatever the task requires. For requiring this adaptability lots of practicing is needed. The fact that expert athletes do have a broader attentional spotlight (horizontally or vertically) does suggest that cognitive expertise is a crucial element in sports. The amount of practice could lead to the difference in size. The ability to train the distribution of attention exists, as seen in the training programs of the UFOV. On the other hand, expert athletes might have chosen their sport based on their affinity with it. It could be that there was already an attentional advantage before they became experts in the sport. It would suggest that the size of the attentional spotlight is something that developed earlier in life or that it is genetic. Which one of these views is correct, must still be determined.

Discussion

The main aim of this research was to describe possible existing individual differences in spatial attention size and their correlation with other cognitive functions and personality traits. This has been done by reviewing different types of study methods and different groups of individuals. This thesis shows that there are differences in default attentional spotlight sizes between groups, but predominantly these groups differ in the ability to adjust the size of the attentional spotlight. The main findings from chapter 4 are summarized in table 4.
A broader attentional spotlight or an attentional spotlight which is flexible in zooming-out can be linked to multiple groups of individuals and their personality traits. These individuals are often very easily distracted and are not able to focus on small features or focus at all. Great flexibility in zooming-out and therefore, being able to broaden the attentional spotlight, is linked to a high creativity level. Individuals with high flexibility in zooming-out are often good at finding different solutions for problems. A broad attentional spotlight could also be an advantage for multiple activities like sports where you have to attend to multiple targets in a broad visual window. The focus of the attentional spotlight must be preserved when the spotlight is broad, a loss of focus would not be beneficial for sports. This loss of focus is visible in the elderly, they get easily distracted by stimuli in the periphery but they are not efficient in detecting them. On the other hand, a narrower attentional spotlight can be linked to more 'narrow-minded' individuals, who are mainly focused on details. In the case of individuals with ASD, being 'narrow-minded' has a significant impact on their scene processing and therefore, experiencing difficulties in everyday tasks. Other individuals with a narrow default spotlight are more flexible in zooming-out, causing them not to experience the same difficulties in life. They can focus their attention more easily on small features and do not get distracted by stimuli in the periphery. These individuals are good at tasks where you just need to follow certain steps, where you do not need to 'think outside the box'.

	Size		Ability to adjust	
	Broader	Narrower	Zooming-in	Zooming-out
Age	Elderly, less focused in periphery	-	Young children are not able when task demands. Young adults and adults are flexible. Elderly are able, but it takes more time.	Children are not able when task demands. Young adults and adults are flexible. Elderly are able but not flexible.
Culture	-	-	-	Western Caucasian have a global preference. East Asians have a greater global preference.
ASD	-	Narrower*	-	Deficit in zooming-out.
ADHD	ADHD-H and ADHD-C	ADHD-I	Local precedence in children.	Neither a global precedence nor a local precedence in adults
Dyslexia	Broader**	-	Deficit in zooming-in.	-
Creativity	Creative and divergent thinkers	Analytic thinkers	-	Creative and divergent thinkers, Very flexible in zooming-out.
Sports	Expert athletes, Shape depends on the sport	-	-	-

Table 4: Overview of the information from chapter 3. No information gained about the conditions in cells containing a (-). *Might be a broader attentional spotlight** Might be a less focused attentional spotlight.

McKone et al., Lao et al., Caparos et al., Wang et al., Rinehart et al., Song and Hakoda, Kalanthroff et al., Henik and Weinbach, Zmigrod et al., Razumnikova and Volf, Zabelina et al. and Cereatti et al. all used a variant of the directed Navon task to investigate the individual differences in the attentional spotlight between groups. The directed Navon task claims to measure the level of adaptability of the size of the attentional spotlight by comparing the global and local processing biases. Dale and Arnell (2013) investigated the reliability of the Navon task by comparing the results of the traditional directed Navon task to an adjusted version which uses shapes instead of letters [10]. Results showed that the adjusted version had a moderate-to-high test-retest reliability and the traditional directed Navon task had low reliability. A suggested explanation for the lower reliability is that in the directed Navon task the participants had to direct their attention, this wasn't the case in the adjusted version. Directing attention may cause noise and therefore, cause lower reliability. Dale and Arnell concluded that the directed Navon task should not be used to compare individuals because of the low test-retest reliability. Their conclusion raises the question of whether the earlier mentioned results from research using the directed Navon task, in which they compared individuals, are even reliable. More research on the reliability of the directed Navon task is necessary if the task is continued to be used to compare individual achievements. Comparing the undirected Navon task with the adjusted Navon task to remove the possible noise added by directing the attention could give new insights into the tasks.

Song and Hakoda used the undirected Navon task to investigate the individual differences in the default size of the attentional spotlight between groups. It is less used compared to the directed Navon task. Therefore, less is known about the task. The undirected Navon task is thought to measure the default or preferable size of the attentional spotlight. There is no evidence that the undirected Navon task is a valid measure for the size of the attentional spotlight. The main problem is regarding the size of the attentional spotlight before the undirected Navon task starts, i.e. during the engagement of attention. Preferably, the attentional spotlight is set to the default size. Then, it adjusts to the global or local level depending on which level is closest to the default size. This would indeed indicate the default size of the attentional spotlight. Another explanation could be that participants know that they need to react to two levels. Therefore, they size their attentional spotlight to an intermediate level and depending on their preference, choose the global or local level. Because of these discrepancies, further research into the sizing of the attentional spotlight before the start of a trial would be beneficial for the validity of the undirected Navon task.

The Navon figures are made of local (small features) and global (large features) to indicate the local of global precedence bias. But what is large and what is small? When is something a local feature or a global feature? Does the relative difference in size between the local and global features matter or are local and global levels determined by absolute size? These questions have not been answered yet. The effect of global and local precedence could results from either relative size differences or absolute size differences. Research into these possibilities would give more insight into the different results in research and could enhance the reliability of the Navon task.

Caparos et al. (2013) stated in their research that local and global perceptual biases must be distinguished from local and global selective attention. Therefore, they question the implications made about the results of the Navon task. The Navon task shows either a local or global perceptual bias in individuals but not local or global selective attention biases. The size or adaptability of the attentional spotlight can not be investigated by the use of the Navon task. If this also accounts for more than just cultural differences has to be researched further, to ensure the reliability of the Navon task.

The Breadth-of-Attention task used by Hütterman et al. (2014) has not been used often. The validity of this experiment is questioned. There are multiple scenarios regarding the attentional changes of the participant. Firstly, the participant does keep their focus on the fixation point and therefore, the maximum breadth of the attentional spotlight can be measured. Secondly, the participant can split their attentional spotlight, and therefore, they do not measure the maximum breadth of the attentional spotlight. They measure the ability to split the attentional spotlight as mentioned before in the multiple spotlight model. Thirdly, the participant switches their attention rapidly between the group of

stimuli on the right and the left. Therefore, they do not keep their focus on the fixation point and they do not measure the maximum breadth of the attentional spotlight. They do measure until which size of breadth the participant can switch their attention without this being noticed. Further research is needed to make sure that the last two scenarios mentioned are not the case. Excluding the possibility of switching attention and splitting the attentional spotlight would make the Breadth-of-Attention task stronger and valid.
The experiment used by Burack (1994) also raises questions. It could be the case that the attentional spotlight does not change at all when the search window appears to be smaller than the default size of the window. It suggests that the smaller search window just narrowed down the area over which the participants had to search for the target stimulus. It is not clear whether this experiment shows the size of the attentional spotlight. Therefore, the possibility of it not measuring the attentional spotlight needs to be considered. Further research is needed to ensure the validity of this experiment.

Whether the cognitive characteristics are a result of the differences in the size and adaptability of the attentional spotlight or vice versa, depends on the group of individuals. For example, the attentional deficit in individuals with ADHD could be a result of a difference in the attentional spotlight or the difference in the attentional spotlight could be the result of the attentional deficit. Another example is the difference between cultural groups. The question remains whether this difference arises from nature or nurture. Does the environment modify the size of the attentional spotlight or is it fixed in the genes? This question could be resolved using the Navon task, as used in the previously mentioned experiments between cultures. This research could be done by comparing four groups of individuals: East Asians who lived their whole life in EA countries, West Caucasians who lived their whole life in WC countries, East Asians who lived their whole life in WC countries, and Western Caucasians who lived their whole life in EA countries. The results would indicate whether cultural differences arise from environmental differences or not.
Specific tasks or jobs have a preferable attentional spotlight size or adaptability level. For example, high demanding jobs such as an air traffic controller or an expert emergency services driver needs flexible and fast adaptable attentional spotlight sizes. One moment they need to focus on the whole scene to spot differences or hazardous events and when something does happen, they need to quickly change their attentional spotlight size to focus on the small event. The inability to quickly and efficiently change the size is a justification for the fact that the elderly are not allowed to do these jobs.
To enhance the mutual understanding between people, it is important to understand why certain individuals have trouble with ordinary tasks. This thesis shows that for example, individuals with ADHD might experience great difficulties in doing something ordinary as grocery shopping. Normally, grocery shopping starts with a global scan of the store, mapping aisles, and find out where you need to go. To get the needed items from your list, you must be able to narrow down the attentional spotlight. Individuals with ADHD however, are not able to narrow their attentional spotlight down. They often wander around the store for a long time, aren't able to choose between different kinds of the same product, they get distracted by all the irrelevant information and it causes them to become overwhelmed. Another very present example also takes place in stores. One of the measures against the coronavirus is the mandatory placement of disinfection pumps at stores entrances. The majority of people would just walk across these pumps, it is a small detail that is not being processed. Meanwhile, individuals with ASD will notice it immediately. The small size of their attentional spotlight in combination with the deficit in zooming-out will cause them to spot the smallest details. Thus, different spotlight sizes or levels of adaptability come with their challenges and benefits.

Conclusion

Individual differences in attentional spotlight size and adaptability do exist. The default size of the focus of attention could either be narrower (enhanced focus on small features) or broader (enhanced focus on large features). The level of adaptability is either very flexible, i.e. individuals are efficient and accurate in zooming-in or zooming-out, or not flexible at all. An overview of the groups of individuals mentioned in this thesis and their corresponding attentional spotlight is shown in table 4. Individual differences are shown to be correlated with cognitive anomalies and personality traits. Individuals show different behaviour which might be the result of either the difference in the attentional spotlight or the cognitive anomalies and personality traits. How these factors correlate with each other differs between the groups of individuals.

The attentional spotlight is important for many aspects of human functioning. Every human functions differently, therefore, more research has to be conducted into the individual differences in spatial attention. It is necessary to further investigate whether the cognitive anomalies result from the difference in the attentional spotlight or vice versa. Thereby, further research into the methods of study used in this field would make the data more compelling and it will provide a stronger theoretical foundation. Existing experimental tasks should be reviewed whether their experimental setup works with all different attentional spotlight sizes. If not, they have to be revised to fit all or they have to develop different versions for different attentional spotlights. Individuals who experience a narrow attentional spotlight or a deficit in zooming-out could also benefit from training programs to enhance the UFOV. For example, individuals with ASD who experience a narrow spotlight or a deficit in zooming-out could benefit from these training programs. Further research into the efficiency of the training programs for other individuals than the elderly is needed. More data regarding the differences in spatial attention between individuals is needed to build a stronger theoretical foundation. Thereby, the mutual understanding between different groups of individuals will increase.

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