Full Attention Location Biases in Image Processing in Young Children

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Abstract

Recent research has demonstrated that adults have a bias to attend to the tops of objects and the bottom of scenes when analyzing visual stimuli. However, no research has examined the presence of this bias in children. Children should be studied to glean information on the origins and purposes of this bias. The current study tested two general hypotheses: (i) children exhibit visual biases for the tops of objects and bottoms of scenes, and (ii) the magnitudes of children's biases do not differ from adults. To test these, participants were shown triptychs (trios of pictures) of either scenes or objects. The trials included (52) natural scene triptychs, and (48) natural object triptychs. The middle picture was an original and the left and right showcased either the top or bottom half of the original combined with the corresponding bottom or top half of a similar but different picture. Participants (N = 50, Ages 4-7) were asked whether the middle image matched the left or the right more strongly. The outcomes of this project confirmed our first hypothesis that children exhibit visual biases and our second hypothesis that they are the same magnitude as adults'. These findings can be used to bolster educational environments and possibly develop treatment programs.

Keywords: children, visual biases, image processing, attention, cognitive development

Introduction

Imagine stepping into a bedroom. Above you the fan swirls, below you the carpet crunches, and in the liminal space between, a scene of one hundred objects unfolds. With all of these visual elements vying for our attention, biases act as mental heuristics to help our brains digest complex visual scenes with ease (Hayes & Henderson, 2019). These biases partition up the visual field and direct attention between the various subsections, allowing people to navigate their environments in chunks. Having an understanding of the mechanics of visual biases could allow interior designers and architects to create intuitive spaces and provide insight for businesses in product design and advertising. Furthermore, various conditions impact visual biases, including certain neurodevelopmental disorders, eating disorders, and addictions. There has even been a visual bias discovered with its roots in the COVID-19 pandemic. Given that visual biases can affect groups differently or emerge when unprecedented times plague us, establishing a base understanding of them will allow for greater exploration of these differences. This mentality is true for exploring children's visual biases as well. As the creators of children's spaces and health interventions, adults owe it to children to understand their perspective and use it to shape their lives with care.

Visual Biases

While the gist of a visual scene can be garnered from a single static viewing, smaller details need special focus to be processed and committed to memory (Henderson, 2007). Fast saccadic eye movements allow gaze fixations, or periods of relative stability, to occur swiftly and repeatedly across the entire visual field (Henderson, 2007). Within a few short moments, an entire scene is able to be assessed, with the help of biases that direct which information is attended to, in what detail, and when. Biases can be manipulated by both top-down and bottom-up influences (Henderson, 2007). For example, A viewer's attention may be attracted by a salient visual element like a pink sunset emerging in a blue sky, or it could be directed by a cognitive goal, like searching for an earring on the bathroom rug. There are many examples of visual biases, and they vary in their intensity, subject, and population.

Location of Information Guides Visual Perceptions

One subsection of visual biases is the variance in perception between objects and scenes. These words are used here to connote aspects of an image or environment, where an object is one singular item and a scene is a larger space. For example, a scene could be that bedroom you pictured earlier and an object could be the desk chair inside it. The difference between how objects and scenes are visualized comes down to how they are interacted with. Typically, when engaging with an object you are likely to focus on the top of it, the part that you more readily see and interact with (Langley, 2020). For example, with the desk chair, you would likely pull on the topmost part and then settle on the cushion in the upper middle region. In a scene, the opposite is true, you favor attending to the bottom of the scene, with your feet on the floor, and your hands manipulating things around your body, mostly engaging with objects below your eye-line (Langley, 2020). Essentially, the most interesting, interactive, and informative elements of an object tend to be at the top whereas the opposite is true for a scene (see Figure 1). Recent findings by Langley (2020) indicate that adults have a top attentional bias in object viewing and a bottom attentional bias in scene viewing, matching the areas of high information saliency.

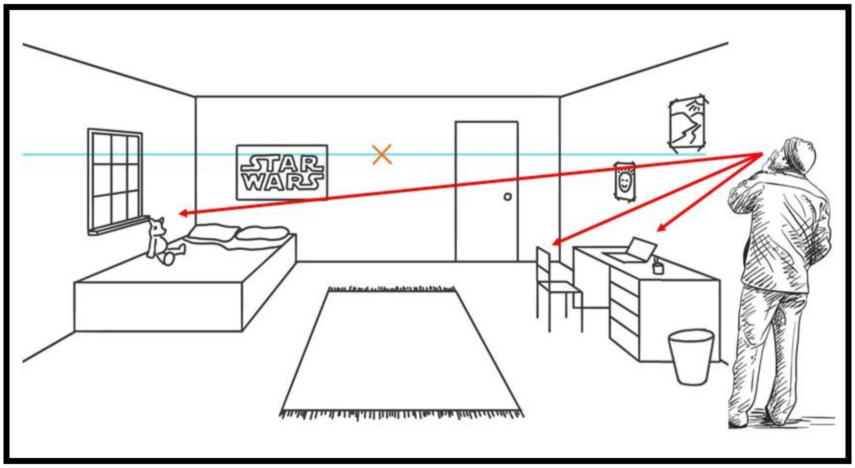


Figure 1. *An example of objects within a scene and the tendency to adopt a general downward gaze that favors attending to the tops of objects and bottom of the scene.*

Visual Biases in Adults

Objects Biases

Another way visual biases can be broken down is by analyzing object versus scene specific biases. Starting with objects, people will assume that an object will be up-right and symmetrical (Chambers et al., 1999). Statistically speaking, it's sensical for these biases to emerge as objects rarely rest on their heads and tend to be created symmetrically to reinforce aesthetic preferences. Furthermore, people attune to objects that are near their hands in preparation to act upon them (Thomas, 2015). There is also evidence that simply owning an object may alter one's perception and memory of it (Truong & Todd, 2017). Truong & Todd provide the example of a piece of luggage deploying at baggage claim: a person waiting for their bag is likely to notice theirs first and remember it that way, even when another bag appears at the same instance (2017).

Scenes Biases

The person waiting at baggage claim is motivated to notice their bag, a goal consistent with that of biases given that they are meant to connect a viewer with important visual information. The Image Guidance Theory does this by directing a viewer's attention to areas of a scene that vary from their surroundings in terms of color, orientation, luminance, etc. (Hayes & Henderson, 2019). The understanding in this theory is that elements of importance are likely to vary visually from less salient background image properties (Henderson, 2007). An example of the Image Guidance Theory is a red square amidst a sea of blue circles, where one's attention will snap to the red square because it is visually distinct from its neighbors. While this has been an influential theory, new research by Henderson and Hayes, shows that it is not always applicable to real-world scenes and that something key is missing (2020). Another general visual bias is the observer center bias which causes viewers to attend to the center of scenes and is largely independent of the contents of the scene or the task the viewer has in assessing it (Hayes & Henderson, 2020). Furthermore, other recent studies demonstrate that attention goes where the viewer suspects the information could be, a bias called the Cognitive Bias Theory. This theory is consistent with Langley's recent findings.

Visual Biases in Children

Children also employ visual heuristics to guide their ocular processing. From prior research, it appears that some of these biases carry into adulthood whereas others are due to developmental asymmetries in visuospatial perception and are resolved prior to adulthood (Poirel et al., 2011)

Objects Biases

For example, one of the biases that children have regarding object orientation is a linguistic bias as well as a visual one. It is called the Whole object constraint and it is the assumption that a word symbolizes the entire object and not just its parts. For example, the word cat refers to the entire animal and not its paws, ears, etc. Children align themselves with this constraint early on and eventually overcome it as it becomes archaic and they familiarize themselves with the various parts that make up larger wholes.

Animals and people appear to be special types of objects for children's visualization. A study on infant perceptions found attentional preferences towards the heads of manipulated cat and dog stimuli, confirming a type of top bias (Quinn et al., 2009). These infants were shown images of a cat head on a dog body and vice versa and then their attentional preference was measured. The infants directed their attention to the heads. This supports that there is either a pre-existing bias to the heads (or faces) in the upper region that it is innate or quickly developed after birth, perhaps because the head region is the most informative place on animals and people.

When viewing objects, children also utilize the shape bias to draw comparisons between them. Two shapes will be rated as more similar if they are shaped similarly rather than other characteristics like color or texture. This bias develops along with noun acquisition and appears around two when children have 50 count nouns (Tek et al., 2012).

Object > Scene Biases

Children perceive scenes differently than adults in some context. Children's scene biases mainly oppose scenes as they tend to favor objects and disregard scenes. This has several possible roots.

Starting with the fact that Children's perception of the visual field is smaller than adults and substantially increases through elementary age. Because of this, the stimuli look bigger to children than to adults (Shirai, Seno, & Morohashi, 2012). This also leads them to favor the objects in a scene over its background elements (Darby et al., 2020).

Also, children think about objects much differently than scenes as their attention to object features matures earlier than their spatial orientation skills (Helo et al., 2016). There is also evidence to support that children's vocabulary contains more object words than scene words and that this helps them attune better to object information (Vales & Smith, 2015). For example, when children were instructed to find something green in a broad scene they had difficulty, despite understanding color words, but when told to find the grass they were able to locate it (O'Hanlon & Read, 2017).

Visual Biases in Diverse Populations

Neurodevelopmental Differences

There can be other impacts on visual perception than age alone. Neurodevelopmental disorders like Autism Spectrum Disorder and Attention Deficit Hyperactive Disorder can be one cause of difference.

For those with ADHD, symptoms like distractibility, impulsiveness, and emotional dysregulation can impact their visual perception which can cause processing differences at the cerebral, cognitive, and behavioral levels (Leroy & Faure, 2020). For example, if a scene contains emotional content, a person with ADHD may be unable to process it in its entirety. This is because more of their attentional resources need to attend to the emotional content in order to try and decipher it. Despite spending more effort in an attempt to understand the emotional content, they still perform worse at it than their neurotypical counterparts (Leroy & Faure, 2020).

Autism Spectrum Disorder is similar to ADHD in that it can be characterized by cerebral, cognitive, and behavioral differences. There is a wide array of these differences but one that particularly impacts visual perception is a social understanding deficit characterized by trouble recognizing emotions, faces, social content, and gestures (Neumann et al., 2006). An example of this that Neumann discusses is that people with autism look more at the mouths of their conversational partners as opposed to their eyes. This is an example of a top-down bias that exists due to cognitive factors rather than the appearance of the stimul itself. Visual differences are so salient between ASD and NT individuals that they are being developed as diagnostic tools to support early intervention (Liaqat et al., 2021).

Object Oriented Disorders

Neurodevelopmental disorders are not unique for having specific visual biases, as other disorders like mood or object disorders can have their own. An object oriented disorder is one that involves or depends on a certain object. These include Eating Disorders where the object of concern is food, addictions where the object can vary from a certain drug, to a beer car, and to Gaming Disorders where attention is focused on a gaming device. (Christiansen, et al., 2015; Jeromin, et al., 2016; Ralph‐Nearman, et al., 2019)

Similarly, though not characterized by a disorder, is the bias towards virus-related stimuli that emerged as a result of the COVID-19 pandemic. Those with higher health anxiety are more likely to attune to virus related information in the stimuli than those with lower health anxiety (Cannito, 2020).

Current Study

While many visual biases have been identified, even beyond what has been listed in this paper, there is still more to uncover about their nature. One area to be extended are the results from Langley which declared vertical attentional biases in adults (2020). The present study, colloquially called, *Behind the Scene,* aimed to investigate these biases in children. Findings revealed whether this visual bias is present across age groups or if it is developed along the lifespan. To do so, this study surveyed young children to determine if they also have a top bias for objects and a bottom bias for scenes.

Hypotheses

The current study tested two general hypotheses: (i) children favor attending to the tops of objects and the bottoms of scenes, and (ii) children's vertical attentional biases do not differ from adults.

Methods

Participants

The children were between the ages of 4 and 7 (Mean Age = 6; SD =1.26). 56.25% of participants were Female and 43.75 % of participants were Male. The ethnic breakdown was as follows: 69% of participants were Caucasian, 19% were Asian, 10% were two or more races, and 2% were American Indian and Alaska Native.

In investigating this question, we chose to work with children in this age range because findings show that children's visual integration abilities increase between the ages of 4-6 (Hupp & Souther, 2014). This increase may be attributed to expanded visual experiences, the start of schooling, or neurological development related to shifting amounts of grey matter in the brain

(Poirel et al., 2011). This age range also represents a middle ground between infants and adolescents, which will be beneficial in narrowing down the emergence of this bias. Also, given that our study requires the at-home use of a computer, we felt it easier to work with children old enough to successfully navigate a computer program.

The adults were between the ages of and (Mean Age = 20.02; SD =2.14) and were recruited from Arizona State University. 67.27% of participants were Female and 32.73% of participants were Male. The ethnic breakdown is as follows: 45.45% of participants were Caucasian, 29.1% were Asian, 12.5% were Black, and 2% were Native Hawaiian or other Pacific Islander, and 10% identified as another race.

Recruitment

Participants were recruited from the Early Childhood Cognition Research Group Database. Parents are invited to sign up for the database through the Emerging Minds Lab social media, word of mouth, and community partners including Busy Bees Babysitting. Recruitment also took place at two local museums, the Arizona Science Center and the Children's Museum of Phoenix. On museum visits, parents were invited to join the database or sign up directly for Behind the Scene.

Compensation

After completing the survey, participants received a $10 dollar gift certificate to a store of their choice such as Target or Amazon, a personalized ASU child scientist certificate, the Emerging Minds Lab activity book, and the Behind the Scenes coloring book.

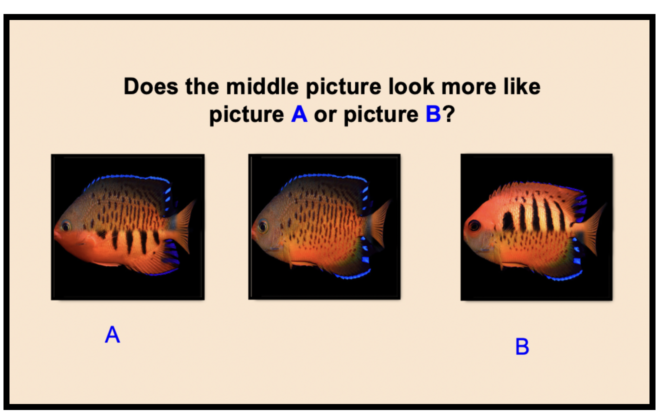
Measures

Test Stimuli

Stimuli consisted of 52 triptychs of highly controlled naturalistic (realistic) scenes and 48 triptychs of naturalistic objects. It was intended to be split evenly, but the final verification revealed an inequality once data collection had already begun. The middle picture in each triptych served as the test case, and the left and right comparison pictures contained either the top or bottom half of the original, combined with the corresponding bottom or top half of a similar but different picture.

Each triptych had a sister triptych that used the other similar picture as the test picture and split the original picture to use as the added random picture half. These pairs of triptychs served as a control for each other in case one of the central pictures happened to be more salient overall. This should limit any bias due to favoring details from one of the two pictures that were combined.

The triptychs were against colored backgrounds and each displayed the same directions, “Does the middle picture look more like picture A or picture B?” The colors were to maintain the children’s attention and the repeated directions were to guarantee that the children would not forget the task at hand.



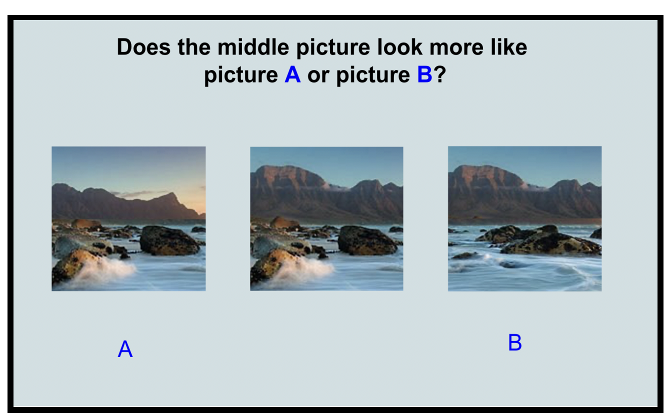


Figure 2. *Examples of one naturalistic object triptych (left) and one naturalistic scene triptych (right) that were shown to the children.*

Supplemental Stimuli

In addition to the test stimuli, there was a virtual toy shop activity embedded within the study. This activity was designed to maintain the children's engagement and prevent them from getting bored of the monotonous task. Images of a teddy bear, a racecar, and two robots were completed as the children progressed in the study, with a new piece added every 5 completed questions. As the toys came to life, entertaining and encouraging rhymes were played aloud. For example, as another piece was added to the second toy robot, participants could hear, "Beep Beep Boop Boop, another robot in the group".

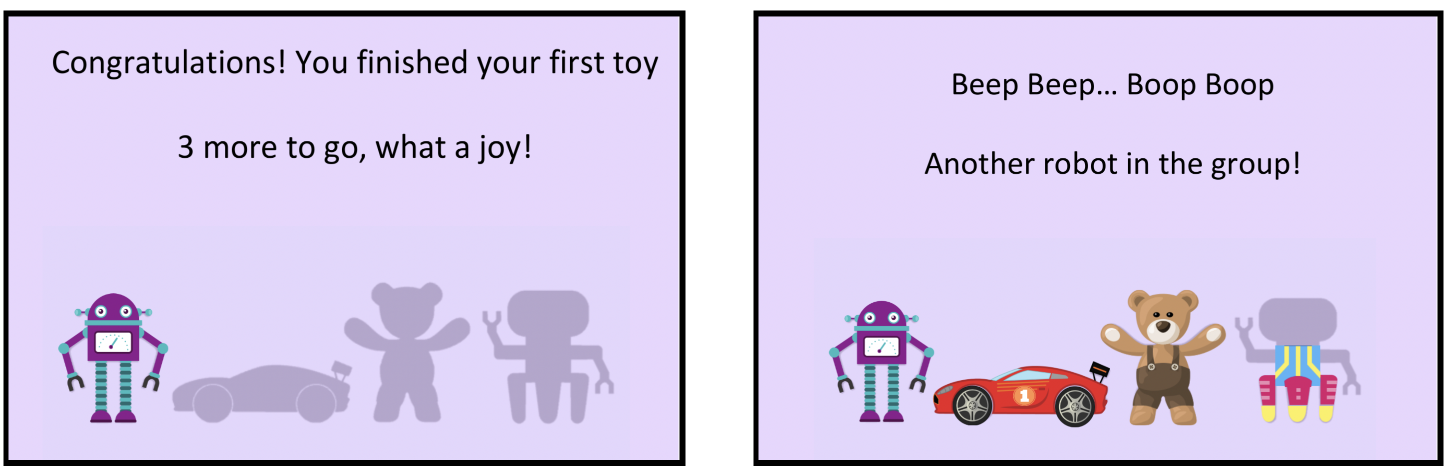


Figure 3. *Examples of the toy build activity and rhyme scheme that the children were shown.*

Procedure

After conducting multiple pilot tests to evaluate the measure, it was determined that the study was appropriate to run in an unmoderated online fashion. Participants were recruited through email or text message and invited to sign up, whereupon they were issued a personal link. The first portion of the survey was for parents and included an instructional video and consent form. The second and primary portion was meant to be supervised by parents but completed entirely by the children. Similarly to the parent section, theirs began with an instructional video and then they were asked for their assent. Finally the measure was presented. Afterwards, parents were debriefed and invited to claim their gift card. Participation terminated when the rewards are dispersed.

Data Analytic Plan

Hypotheses Testing

Data Analysis was conducted using Excel and R for Data Science. Following the culmination of data collection, results were imported into an excel spreadsheet for cleaning. The irrelevant data was removed, demographic data was separated out, and meaningless As and Bs were converted into 0s and 1s, where each top response was coded as 1. The data was sorted into a short form where each participant was represented by two mean scores that reflected their scene and object means.

Once the data was cleaned in excel, the form was fed into R for analysis. In R, preliminary analysis included running summary statistics of the files and creating graphic visualizations. From there, a factorial Anova analyzed the impact of the factors: age and trial type on the mean scores. This Anova also examined the interaction between age and trial type.

Furthermore, eight t-tests ran next, four One Sample t-tests compared each group to chance, and four Two Sample t-tests compared children’s scenes and object scores, children’s scenes and adult’s scenes, children’s objects and adult’s objects, and adult’s scenes and adult’s objects. Cohen's D was used to analyze the effect sizes.

Exploratory Analysis

Demographic information was used to run exploratory analyses. Height, gender and handedness were analyzed and visualized to reveal any interactions they had with mean scores.

Results

Hypotheses

The results of the analyses reveal support for Hypothesis 1 and support for Hypothesis 2. For the first hypothesis, both adults and children rate that objects are more similar when they share the same top and that scenes are more similar when they share the same bottom. A factorial anova revealed a significant difference between scenes and objects on the mean score and a Cohen’s D test revealed a very large effect size, $F(1,202)=1258.084$, $p=2.2e\text{-}16$*, d=4.8669. There was no significance of age on the mean score. However, there was an interaction effect between age and trial type, $F(1,202)=8.308$, $p=0.004$*. These results were confirmed in one sample t-tests comparing each group to chance as well as two sample t-tests comparing relative groups against each other. Meaning that both children's groups were compared, both adult groups, both scene groups, and both object groups. The results for these tests are below.

Child - Object	**Child - Scene**	**Adult - Object**	**Adult - Scene**
t(48)=54.344, *p*=2.2e-16*, *d*=2.2878	*t*(48)=14.392, *p*=2.2e-16*, *d*=-2.1712	*t*(54)=75.055, *p*=2.2e-16*, *d*=3.3838	*t*(54)=12.78, *p*=2.2e-16*, *d*=-2.430
Child - Child	**Object - Object**	**Adult - Adult**	**Scene - Scene**
t(87.95)=21.578 p=.2.2e-16*, d= 4.494	t(91.34)=-2.7612 , p=.007*, d= -0.9508	t(89.86)=28.51, p=2.2e-16*., d= 6.1036	t(100)=1.5768, p=.118, d=0.5142

Figure 5. *One and Two Sample T-Test results.*

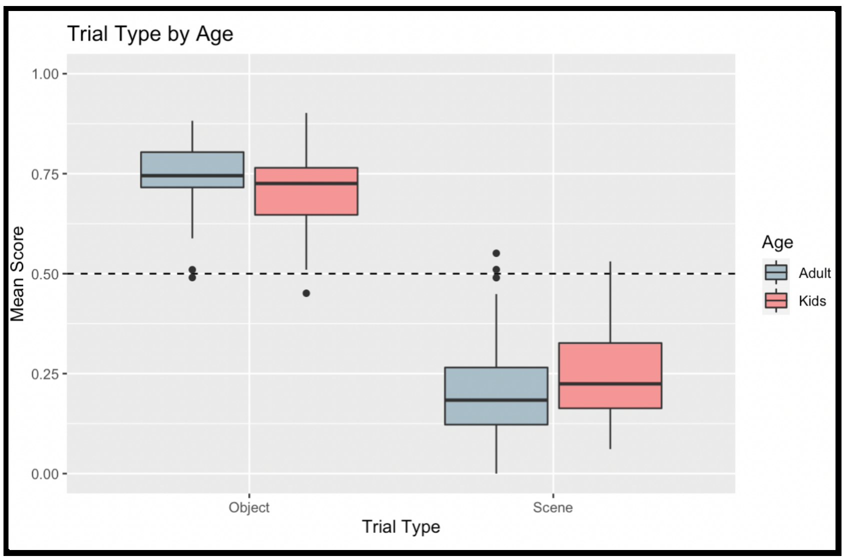


Figure 6. *A box and whisker plot showing that compared to chance, both adults and children rate objects as more similar to those with the same top, and that for scenes they rate scenes as more similar when they share the same bottom*

Exploratory

Across demographic factors, there was little to report for handedness or gender. T-tests revealed no significant difference between Male and Female participants or between left handed, right handed and ambidextrous individuals. Height data on the other hand did yield interesting results. In the Child Scene group there was a significant correlation between the height of a participant and their mean score, , $r(46) = -1.839$, $p = 0.072$. This was the only group to have a significant correlation between height and score. Interestingly though, the age of the participant had a stronger correlation with mean score than height, $r(46) = -2.589$, $p = 0.012$.

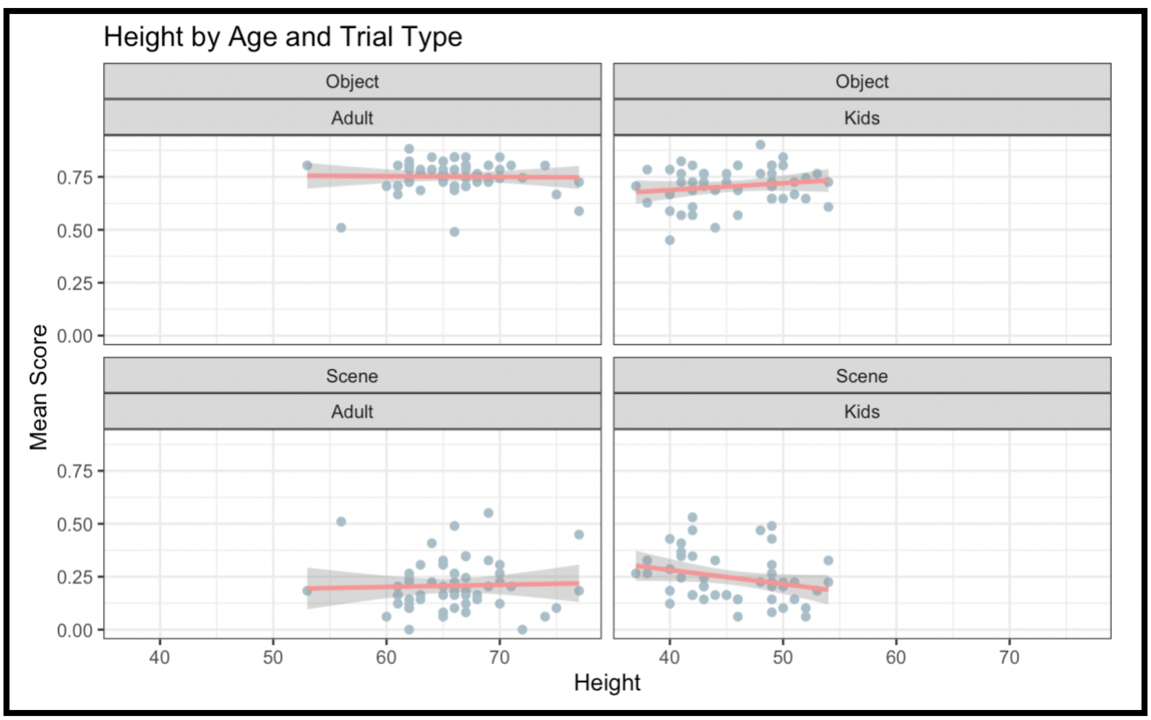


Figure 7. *A faceted line plot to show the effect of height on mean score*

Discussion

Hypotheses Results

The original hypothesis was determined on the basis that children would behave in line with adults. There was little reason to hypothesize otherwise for objects, but there was some question about scenes. Given that children are shorter, and much of the same environmental elements below adults' sightline are above children's, it was questioned whether they would orient themselves differently when looking at scenes. In the end, the results showed that children do show vertical biases for both the tops of objects and bottoms of scenes.

Exploratory Results

However, their height may still play a role in the development of this bias. The results revealed an effect of height on the mean scores, where the tallest children were behaving the most similar to the adults. As expected, this had a stronger effect on the scene condition than the object condition.

Implications

The implications of these results are that scenes and objects are distinct visual stimuli that get treated differently during perception. Given that biases aid in quick processing, there is something about the difference in scenes and objects that influences the opposite biases. From the prior research it is understood that information location and saliency can alter perception, and given that scene and object information is counter weighted; it can be gleaned that this information distribution plays a role. This seems to be a bottom-up bias, impacted by the stimuli itself and the concentration of information in scenes versus objects. These biases are similar to the Cognitive Bias Theory that state a person attunes to the stimuli based on where they believe the important content to be. From the work on the Image Guidance Theory, it seems that Hayes and Henderson were correct in their assumption that other informational content impacts perception stronger than visual saliency alone (2020). It is likely that visual saliency is a starting point, and possibly a rudimentary bias to be relied on when other biases are not at work.

For children specifically, the implications are that the top and bottom biases for objects and scenes are developed at least by age 4, the lowest age in the cohort.. However, it seems that the smaller visual field and difference between object and scenes in cognitive development does not prevent children from developing this bias while still holding others. This is an example of a children's visual bias that does progress into adulthood.

Future Directions

Younger Children

Given that there is a trend for height and age in scene biases, it is still important to research this in younger children. The trend states that as children grow in age and height, their bias for scene visualization is impacted. Running this experiment on infants, similarly to the work on infant's head biases, would help determine further the origins of this bias.

Height v Age Study

Given that age and height typically grow together, it is difficult to determine whether it is one of these individual factors, or an interaction that is causing the correlation. In the future, it would be interesting to study the effects of height more carefully. Comparing various adult groups with extreme height averages such as NBA Basketball players and US Gymnasts, will help us determine if height still impacts visualization post adolescence. Also reexamining children in the same way, by gathering outlier groups and testing them against the average, could help parse out whether it is height or age impacting the bias development.

Cross-Cultural Study

Like many constructs, evidence supports cross-cultural differences on visual perception. Westerners tend to focus more on salient objects within scenes and do not explore entire scenes to the same degree that eastern individuals do (Goh & Park, 2009). This aligns with cultural practices in the west that promote focus and individualism whereas eastern cultural practices tend to be holistic and for the collective. A fascinating future study could examine how cultural norms impact visual biases.

Priority of Visual Biases

Throughout this work many different visual biases have been identified. If biases are meant to act heuristically and direct attention, then how do they perform when multiple biases could be enacted? For example, a salient red square at the top of a blue scene of sky and ocean. Will the bottom bias or saliency bias win out? What if the bias is being enacted from the top-down such as looking for a dropped earring, will this goal override any other bias that would have been employed? Future research could develop a study to systematically present participants with competing biases in order to rank the utilization.

Intervention Applications

Understanding the baseline for children's biases could also help develop interventions for eating disorders, alcohol and drug abuse disorders, and anxiety disorders in adolescents. Visual biases are altered in these populations to specifically attend to the individuals' hyper-sensitive stimuli (e.g. food, bodies, drugs, fear-inducing stimuli, etc.) (Field et al., 2004; Maratos &

Staples, 2015; Ralph‐Nearman et al., 2019). Attentional Bias Modification has been employed in the past as an intervention for Substance Use Disorders (Christiansen, Schoenmakers, & Field 2015). The results from this intervention show lowered Attentional Biases but mixed evidence on behavioral outcomes. Future research should examine the longitudinal effects of Attentional Bias Modification.

Conclusion

It seems that attentional biases in visual processing exist in a wide variety of paradigms. From general biases that impact nearly all sighted-individuals, to time-period biases like the health-related object visual bias that appeared during the COVID-19 pandemic, to group-specific biases that only affect certain populations. Bit by bit research unearths new biases or information that helps understand them. This study helped extend Langley's findings on vertical attentional biases to include children and opened up new research questions to be explored.

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