Using detection or identification paradigms when assessing visual development: Is a shift in paradigm necessary?

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Given the inherent difference in judgment required to complete visual detection and identification tasks, it is unknown whether task selection differentially affects visual performance as a function of development. The aim of the present study is therefore to systematically assess and contrast visual performance using these two types of paradigms in order to determine whether paradigm-contingent differences in performance exist across different periods of development. To do so, we assessed sensitivity to both luminance- and texture-defined stationary and dynamic gratings using both detection and identification paradigms. Results demonstrated a relatively unchanged *pattern* of performance from the school ages through adolescence, suggesting that sensitivity was not differentially affected by choice of paradigm as a function of development. However, when averaged across age groups, a paradigm-contingent difference in sensitivity was evidenced for dynamic, texture-defined gratings only; it was easier to *detect* the spatial location of the gratings compared with *identifying* the direction of their motion. Paradigm-contingent differences were not evidenced for luminance-defined stimuli (whether stationary or dynamic), or for stationary, texture-defined gratings. In general, visual performance measured using either detection or identification paradigms is comparable across ages, particularly when information is stationary and defined by more simple visual attributes, such as luminance. Therefore, the use of detection paradigms might be advantageous under most circumstances when assessing visual abilities of very young and/or clinical populations in order to minimize potential challenges not related to visual perception (i.e., attentional) in these populations. Finally, paradigm-contingent differences in performance specific to dynamic, texture-defined information will be discussed.

Keywords: detection, identification, visual development

Citation: Hanck, J., Cornish, K., Perreault, A., Kogan, C., & Bertone, A. (2012). Using detection or identification paradigms when assessing visual development: Is a shift in paradigm necessary? *Journal of Vision, 12*(6):4, 1–9, http://www.journalofvision.org/content/12/6/4, doi:10.1167/12.6.4

Introduction

Different types of experimental paradigms are available to researchers when designing studies assessing specific cognitive functions. In the perceptual domain, various forms of *forced-choice* paradigms are often used to measure thresholds that define performance reflecting a specific visual function. In such cases, observers are often asked to choose between one

doi: 10.1167/12.6.4 Received September 29, 2011; published June 1, 2012 ISSN 1534-7362 © 2012 ARVO

of two alternatives presented to them, where they are asked to (1) *detect* whether a stimulus is present in one of two spatial locations or temporal intervals, or (2) *identify* or discriminate a specific, predetermined attribute of a stimulus (i.e., its orientation either vertical or horizontal). These two types of tasks differ mainly with respect to the nature of judgment required to obtain a perceptual threshold. The judgment required for an identification task is typically more complex than that needed for a detection task because, for the former, participants are required to identify a specific property of a stimulus that must be maintained in memory across task, whereas, in the latter, participants need only detect the presence of a target stimulus.

Thomas (1985) proposed that detection and identification tasks are closely related because they both depend on the encoding of perceptual information by the visual system and share two sequential stages. The first is an encoding stage that describes how physical stimuli activate specific pathways and how they are represented at a neural level within the visual system. The second is a decision stage that describes how these responses are combined and tested against a decision rule in order to select the judgment to be made. Thomas (1985) argues these two types of tasks represent *different* uses of this information given that they rely on different decision processes regarding the *same* neural representation of the visual scene. In addition, some theories of object recognition postulate that the detection of an object by the visual system (e.g., object contours) occurs before these parts are identified (e.g., Marr, 1982; Biederman, 1987; Nakayama, He, & Shimojo, 1995; see also Treisman & Gelade, 1980). For example, Sagi and Julesz (1985) argue that stimulus detection is best characterized as a preattentive, parallel process as opposed to identification or discrimination, which is described as a serial process requiring attention. These theories argue that detection processes precedes those of identification in order for object recognition to be more efficient.

Empirical evidence for distinct mechanisms for the mediation of visual detection and identification processes has been demonstrated in adult populations (Kitterle, Christman, & Hellige, 1990; Hillis & Brainard, 2007; de la Rosa, Choudhery, & Chatziatros, 2011), including elderly adults (Bennett, Sekuler, & Sekuler, 2007). For example, Straube & Fahle (2011) contrasted shape detection versus identification of a figure and found that the identification paradigm yielded higher thresholds and slower reaction times compared with the detection paradigm. The fMRI measures component of their study demonstrated in part separate cortical mechanisms for object detection and identification. Grill-Spector and Kanwisher (2005), for instance, found that although no significant differences in reaction time and accuracy between object detection and/or categorization paradigms occurred, substantially more processing was required to identify the same objects. Task-dependent differences have also been demonstrated at a neuronal level. For example, Hol and Treue (2001) demonstrated that different neuron populations underlie the detection and discrimination of motion within the context of an adaptation paradigm. In addition, paradigm-contingent differences in performance may be related to the physical attributes defining the stimuli used in the task, such as the spatial frequency, or under certain experimental conditions (Olzak, 1985). It is therefore unclear whether choice of experimental paradigm and the defining physical attributes affects performance on most assessments of perceptual functioning in adults.

This argument is exemplified by the work of Dobkins and colleagues, who assessed the contribution of the M and P pathways in motion processing during development. Using a motion (MOT)/detection (DET) paradigm, previously used in adults (e.g., Watson, Thompson, Murphy, & Nachmias, 1980; Green, 1983; Graham, 1989), Dobkins and Teller (1996) contrasted thresholds for the detection of a moving stimulus and compared them with those obtained using a discrimination task for the same stimulus in both adult and infant (3 months old) groups. They argue that using this approach allows for the assessment of direction discrimination while controlling for stimulus detectability (see Dobkins and Teller, 1996, for methodological details). When the MOT/DET paradigm produces a ratio of near 1 (threshold for detection of motion/threshold for identification of motion), a limited contribution of paradigm on the threshold obtained is suggested. However, ratios significantly different than 1 indicate that the contrast levels needed for detection are not sufficient for the identification of a moving stimulus. For example, Dobkins and Teller (1996) measured MOT/DET ratios for both luminance- and chromatic-defined (nonluminance) information in order to assess the contribution of the M and P pathways respectively to motion processing during development. They found that, in adults, MOT/DET ratios reflecting M (luminance) processing near 1 indicates that the amount of luminance contrast needed to detect a moving stimulus is enough to permit the discrimination of that same stimulus. However, the MOT/DET ratio for the P (chromatic) mechanisms are significantly higher, suggesting that the chromatic, nonluminance-defined contrast levels required for detecting a stimulus are not sufficient for the discrimination of the direction for that same stimulus in adults (Dobkins & Teller, 1996). Although the motivation for comparing MOT/DET is different from that of the present study, it demonstrates that the choice of task will differentially affect performance, particularly when comparing such performance across stimuli that are defined by different physical attributes.

While many studies have assessed early perceptual functioning in developing children using either detection or identification paradigms, none have compared visual performance with these two paradigms in the same child population targeting the same visual functions using the same stimuli. The motivation, therefore, for the present study was to address the question of whether the type of paradigm used to assess early perceptual function—detection vs. identification—differentially affects performance as a function of development. Specifically, our aim was to systematically assess and contrast these two types of paradigms in order to determine whether paradigm-contingent differences in visual performance exist across age groups ranging from 5 years to adulthood. This was addressed by measuring thresholds to luminance- and texture-defined information presented across two different temporal frequencies: a static condition (0 Hz) and a dynamic condition (2 Hz) using detection and identification paradigms. Although we describe our stimuli categorically (static-0 Hz vs. dynamic-2 Hz), we are well aware that sensitivity will change as a function of temporal frequency; however, this is beyond the scope of this study (Hutchinson & Ledgeway, 2010).

Complexity was manipulated by using both luminance-defined and texture-defined stimuli. Luminance information is considered to be simple because it is initially processed by standard motion/orientation selective mechanisms operating within the primary visual cortex (or V1), whereas texture information can be considered to be more complex because it recruits more extensive additional processing and neural circuitry after V1 before its detection (Ashida, Lingnau, Wall, & Smith, 2007; Larsson, Landy, & Heeger, 2006; Smith, Greenlee, Singh, Kraemer, & Hennig, 1998). In addition, if presented in static or dynamic forms, luminance and texture information is initially processed in a comparable manner by separate feed-forward mechanisms that use similar principles of detection (Baker, 1999; Chubb & Sperling, 1988; Nishida, Ledgeway, & Edwards, 1997; Sperling, Chubb, Solomon, & Lu, 1994; Sutter, Sperling, & Chubb, 1995; Wilson, Ferrera, & Yo, 1992). An advantage to using these testing conditions is that it becomes possible to see whether differences in paradigms are dependent on increasing the load on the system (i.e., increasing complexity). Finally, although stimuli and procedures that we and others have utilized to assess visual development are used (Bertone, Hanck, Cornish, & Faubert, 2008; Kogan et al., 2004; Armstrong, Maurer, & Lewis, 2009), our results may apply to other commonly used metrics of lower-level visual performance during development (i.e., global form vs. global motion perception, etc.).

Method

Participants

Participants were recruited through advertisements in a local family magazine in Montreal and from an already established database at the McGill Child Laboratory for Research and Education in Developmental Disorders. A total of 51 typically developing participants with normal or corrected-to-normal vision were placed into five age groups: (i) 5–6 years, n = 10, mean chronological age (CA) = 5.8 ± 0.6; (ii) 7–8 years, n = 10, mean CA = 8.12 ± 0.62; (iii) 9–10 years, n = 11, mean CA = 9.98 ± 0.64; (iv) 11–12 years, n = 10, mean CA = 12.21 ± 0.39; and (v) 18–35 years, n = 10, mean CA = 22.22 ± 2.73.

Their verbal mental age (Peabody Picture Vocabulary Test-III, PPVT-III) fell well within norms for their age (5–6, mean verbal age [MA] = 6.54 ± 1.64; 7–8, mean MA = 8.81 ± 1.49; 9–10, mean MA = 12.11 ± 3.86; 11–12, mean MA = 17.15 ± 2.75). Participants were compensated for their time and were instructed that they were free to withdraw from the study at any time. Testing commenced after ethics approval was granted by the ethics committee at McGill University, consistent with the guidelines and tenets of the Declaration of Helsinki.

Apparatus

Stimulus generation, presentation, and data collection were controlled by a MacPro G4 computer using the VPIXX© graphics program. Stimuli were presented on a calibrated 18-inch Viewsonic E90FB .25 CRT monitor (1280 × 1024 pixels), refreshed at a rate of 75 Hz. The mean luminance of the display was 50.0 cd/m2, where L_{min} and L_{max} were 0.5 and 99.50 cd/m2, respectively. Gamma correction was verified using a Minolta CS-100 Chroma Meter colorimeter on a regular basis.

Design and procedure

Participants were tested individually in a dimly lit room. Procedural instructions were given verbally to each participant prior to each experimental block. Practice trials were completed to familiarize participants with fixation, stimuli presentation, and responding. The stimuli, procedure, and experimental paradigms used were similar to those used previously by our group (i.e., Bertone et al., 2008; Kogan et al., 2004) and others (Armstrong et al., 2009; Ledgeway & Smith, 1994). Briefly, stimuli consisted of luminance- or texture-defined gratings (1 cpd) that were either static (moving at 0 Hz) or moving either left or right at 2 Hz. All stimuli were 10×10 degrees in visual angle when viewed from 57 cm. For the detection paradigm, the center of stimulus was 6.5 degrees visual angle to the left and right of the center of the screen (Figure 1).

Sensitivity (1/threshold) to static and dynamic processing for luminance- and texture-defined stimuli was assessed using (1) an identification paradigm and (2) a detection paradigm (Figure 1). For the *identification paradigm,* a single-interval, two-alternative, forced-choice procedure was used where participants were asked to identify by verbal response either the orientation (vertical or horizontal) or direction (left or right) of centrally presented gratings (750-ms presentation time) for static and dynamic conditions, respectively. For the *detection paradigm,* participants were asked to indicate by verbal response which of two spatial locations contained the grating, regardless of its orientation (vertical or horizontal) or direction of its motion (left or right). The adult group responded by pressing either of two buttons on the keyboard. An adaptive staircase procedure (maximum likelihood parameter estimation by sequential testing; Harvey, 1997) was used to measure identification and detection thresholds for luminance-defined gratings and texture-defined gratings.

For all conditions, the first presentation of each staircase contained a maximally visible (100% luminance or texture modulation) grating followed by three subsequent trials with suprathreshold gratings whose orientation/direction was relatively easy to identify (based on pilot testing) or detect. The experimenter remained present throughout testing and initiated successive trials while monitoring fixation and fatigue. Testing sessions ended after a 90% confidence level that the threshold estimate fell within ± 0.1 log units of the true measure. The experimental session (including PPVT/EVIP assessment) took approximately 60 minutes to complete. Half of the participants tested in each age group completed the identification paradigm first, whereas the other half completed the detection paradigm. All participants, including the adults, were inexperienced psychophysical observers.

Results

Contrast thresholds for the correct identification or detection of static and dynamic luminance- and texture-defined stimuli were expressed in terms of sensitivity (1/threshold for luminance- and texture-defined conditions). All data were log-transformed before two separate repeated measures. $5 \times 2 \times 2$ ANOVAs were used to assess the effect of age (between factor: five levels), paradigm (within factor: two levels; detection vs. identification), and condition (within factor: two levels; static vs. dynamic information processing) for luminance- and texture-defined stimulus conditions.

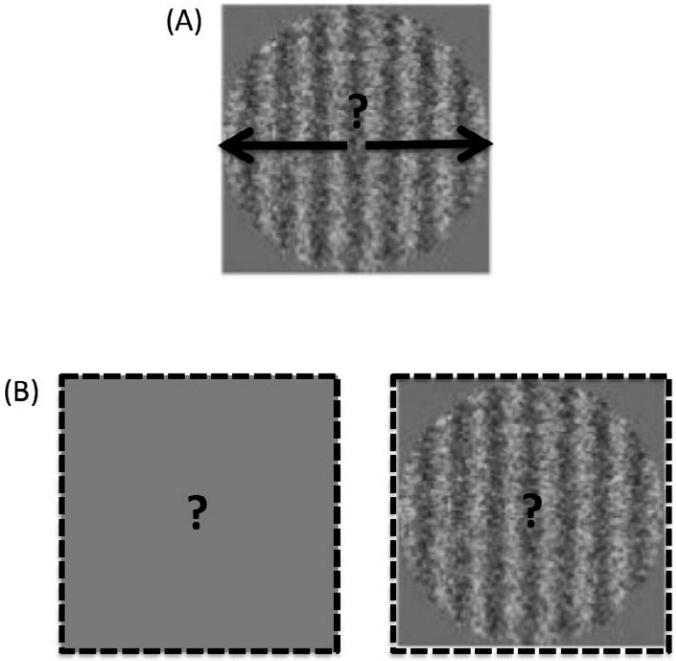

Figure 1. Schematic representation of stimuli used in the identification and detection paradigms. For the identification task (a), static (orientation-identification task; gratings presented either vertically or horizontally) and dynamic stimuli (direction-identification task; stimuli moving either to the left or to the right) were presented in the center of the screen for both the luminance (upper panels) and texture (lower panels) conditions. Participants were asked to identify the orientation or direction of the stimuli. For the detection task (b), stimuli were presented either to the right or left of the screen's center (stimuli center presented 6.5 degrees from screen's center). Participants were asked to detect where the stimulus was located (left/right) on the screen, regardless of its orientation and/or direction.

For luminance-defined stimuli, a main effect of condition (static vs. dynamic) was evidenced (F [1, 46] = 1349.904, $p < 0.0005$), demonstrating that sensitivity to dynamic information processing is higher compared with static information processing (Figure 2). A main effect of age was also evidenced (F [4, 46] = 15.568, $p < 0.0005$). Pairwise comparisons with a Bonferonni-corrected alpha level of 0.005 revealed that the mean sensitivity of 5–6-year-olds was significantly lower than that of the 9–10-year-olds ($p = 0.002$), 11–12-year-olds ($p < 0.0005$), and the adult group ($p < 0.0005$), but not to that of the 7–8-year-olds ($p = 0.03$). Additionally, the mean sensitivity of 7–8-year-olds was significantly lower only to that of adults ($p = 0.001$), but not compared with the 9–10-year-old ($p = 1$) nor 11–12-year-old groups ($p = 0.222$). The mean sensitivity of both the 9–10-year-old and 11–12-year-old groups did

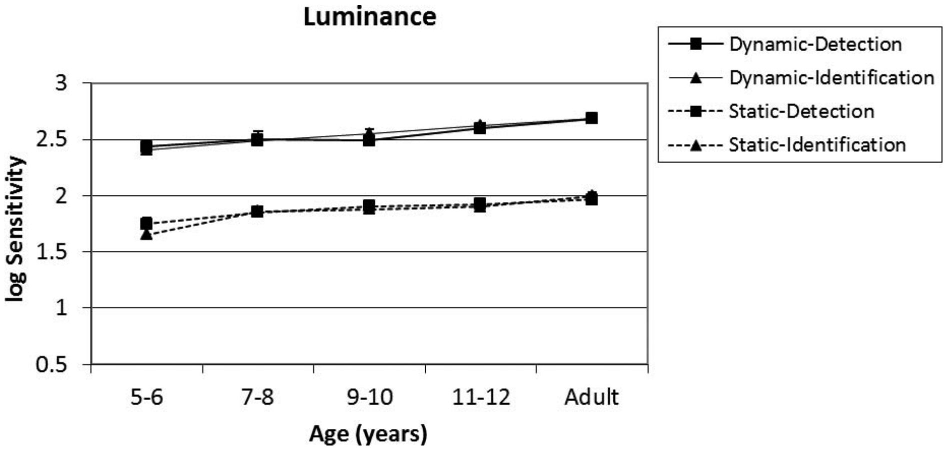

Figure 2. Solid lines represent the sensitivity to dynamic luminance-defined stimuli for both detection (squares) and identification (triangles) paradigms as a function of age group. Sensitivity to static luminance-defined stimuli is represented by the dotted lines for both detection (squares) and identification (triangles) paradigms. When visible, error bars represent the standard error of the mean.

not differ from that of the adult group (p = NS). Importantly, a main effect of paradigm (detection vs. identification) was not evidenced for either static or dynamic conditions across age groups ($F\,[1, 46] = 0.149$, p = NS), indicating that, for luminance-defined stimuli, choice of paradigm did not affect performance. Furthermore, significant interactions effects between variables (three-way and two-way) were not evidenced.

For texture-defined stimuli, a significant interaction between condition and paradigm was evidenced ($F\,[1, 46] = 14.166$, $p < 0.005$) (Figure 3). Simple effects demonstrated that the sensitivity to dynamic information was higher compared with static information processing across age groups for the detection paradigm only ($F\,[1, 46] = 32.7205$, $p < 0.0005$); differences were not found for the identification paradigm. A main effect of age was also evidenced ($F\,[4, 46] = 9.241$, $p < 0.005$) when sensitivity was averaged across paradigm and condition. Pairwise comparisons with a Bonferonni-corrected alpha level of 0.005 revealed that the mean sensitivity of 5–6-year-olds was significantly lower than that of the adult group ($p < 0.0005$), but similar to the other age groups (7–8- [$p = 1$], 9–10- [$p = 0.3999$], and 11–12-year-olds [$p = 0.021$]). Additionally, the mean sensitivity of 7–8-year-olds was significantly lower only to that of adults ($p = 0.001$), but not to the 9–10-year-olds ($p = 1$) nor the 11–12-year-olds ($p = 0.594$). Finally, the mean sensitivity of the 9–10-year-old group was similar to that of the 11–12-year-old ($p = 1$) and adult groups ($p = 0.006$).

In a second analysis, the sensitivity for detecting a stimulus was compared with that for identifying its direction for each condition across age groups, resulting in a ratio of performance that isolates the information available when making a certain judgment across tasks (Dobkins & Teller, 1996). A ratio of around 1.0 suggests that the luminance or texture information (contrast) necessary for detecting a stim-

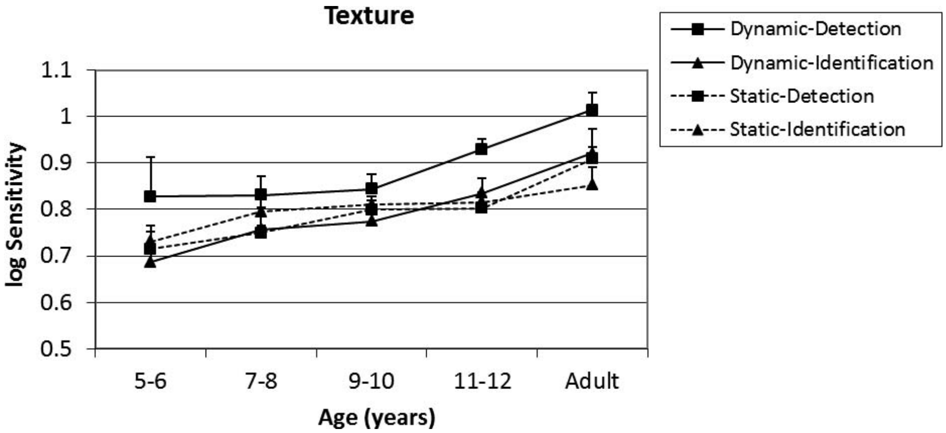

Figure 3. Solid lines represent the sensitivity to dynamic texture-defined stimuli for both detection (squares) and identification (triangles) paradigms as a function of age group. Sensitivity to static texture-defined stimuli is represented by the dotted lines for both detection (squares) and identification (triangles) paradigms. When visible, error bars represent the standard error of the mean.

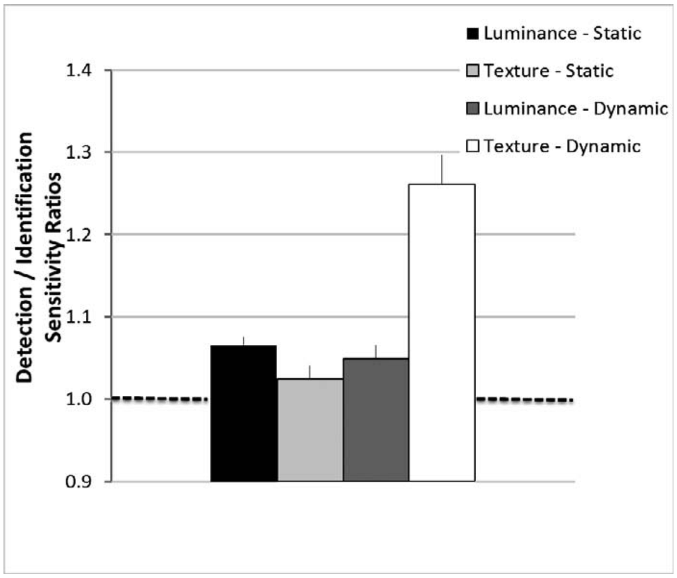

Figure 4. Detection/identification sensitivity ratios for luminance- and texture-defined conditions (static and dynamic) collapsed across age groups is shown. A ratio of approximately 1.0 suggests that the luminance or texture contrast needed for detecting a stimulus is approximately the same as that for identifying its direction. N.B. The detection/identification sensitivity ratio differed (above 1) for the dynamic texture-defined condition, with a ratio of 1.26.

ulus is approximately the same as that for identifying its direction (see Dobkins & Teller, 1996, for methodological details). The ANOVA revealed a significant main effect of condition (F [3, 203] = 5.828, $p = 0.001$) (Figure 4), a Dunnett (two-sided) post-hoc t-test revealed that the detection/identification sensitivity ratio for the texture-dynamic condition was significantly higher than that of the luminance-static ($p = 0.007$), texture-static ($p = 0.003$), and luminance-dynamic conditions ($p = 0.001$). Interestingly, whereas the average sensitivity ratio for the texture-dynamic condition was 1.26, the ratios of the other three conditions was close to one, indicating that the choice of paradigm (detection vs. identification) did not differentially effect performance for these conditions (see Discussion).

Discussion

Differences in perceptual performance when using identification versus detection paradigms has been extensively examined in the adult literature. However, this represents the first study to our knowledge to assess the presence, or absence, of task-contingent differences in visuoperceptual performance from the school ages through adolescence and into adulthood. Although the choice of paradigm can be argued to be inconsequential on performance for most tasks when assessing adults, it is unknown whether type of paradigm differentially affects performance when assessing observers whose task comprehension may be compromised, as is the case for young participants, or observers with cognitive challenges (i.e., attentional, memory-related, left-right confusion, etc.) resulting from atypical development. This possible paradigm-dependent dissociation is especially important when assessing performance across a large age range, where such cognitive effect may interact with perceptually related performance.

Previous studies examining the development of spatial and dynamic information processing in school-aged children have used a variety of stimuli and task paradigms (detection vs. identification) to do so. Such different experimental combinations may at least in part explain the generally inconsistent results previously found. For example, Parrish, Giaschi, Boden, and Dougherty (2005) examined dynamic and static perception at different levels of analysis (local vs. global) using an *identification* paradigm. In one experiment, participants were asked to identify different shapes defined by motion, texture, or luminance contrast. Results indicated a developmental profile suggesting that segregation based on motion contrast matured (i.e., reached adult-like levels) before that of luminance, then texture contrast. However, Gunn et al. (2002) demonstrated an opposite developmental profile for figure/ground segregation when using a *detection* paradigm (texture contrast matured earliest). It is therefore unclear whether the different developmental profiles in these studies originated from the type of paradigm used to extract thresholds (identification vs. detection) and whether the choice of paradigm differentially affected performance as a functioning of age and type of information assessed (i.e., static vs. dynamic; local vs. global).

In the present study, identification and detection paradigms were compared across a number of different conditions (luminance vs. texture; dynamic vs. static) and ages (5 years to adulthood) in order to determine whether type of paradigm used differentially affected performance at different developmental periods. Furthermore, our use of different conditions (static vs. dynamic) using similar stimulus properties enhances the comparability of the results to other studies (Kogan et al., 2004; Bertone et al., 2008; Armstrong et al., 2009). Although charting the developmental trajectories was not the primary goal of this study (see Bertone et al., 2008; Armstrong et al., 2009; Bertone et al., 2010), our results indicate that adult-like performance (collapsed across condition [static/dynamic] and paradigm [detection/identification]) was reached at 9–10 years of age.

The main finding from the present study is that the choice of paradigm (identification vs. detection) did not differentially affect performance *as a function of age* for either of four stimulus conditions tested (no interaction age × condition effect was found). This means that, in general, the same relative pattern of performance was manifested at each age group with regards to the stimulus conditions tested. Interestingly, when comparing paradigm-contingent sensitivity, the only difference found was for the texture-defined, dynamic condition where sensitivity was consistently higher for detecting, compared with identifying, the motion of texture-defined stimuli; paradigm-contingent differences were not manifested for either of the luminance conditions, nor for the static, texture condition. Our findings are similar to Dobkins and Teller (1996) in that second-order stimuli—either chromatic in the case of Dobkins and Teller (1996) or texture-defined as in our study—are easier to detect than to identify. Although they did find that, this was not the case in very early development (3 months).

We argue that this specific task-dependent difference may be due to the fact that texture-defined or second-order motion mechanisms in adults are less directionally selective than those mediating luminance, or first-order motion mechanisms (Ledgeway & Hess, 2002). For this reason, relative to luminance information, the ability to detect dynamic texture-defined information would be easier than identifying its direction of motion. In addition, the absence of significant differences in sensitivity to the identification vs. detection of static stimuli could be limited to the simple-type physical differences in the parameters we chose and may not be applicable to higher-level (complex visual forms and/or objects). For example, Straube and Fahle (2011) found different mechanisms for the detection and identification of their stimuli (figure identification and detection) as demonstrated by significant differences in psychophysical thresholds, reaction times, and imaging results. Further research should examine the effect of temporal frequency on a wider continuum across ages.

Given that both paradigms were found to be equally sensitive for assessing the development of specific visual mechanisms, we suggest that a priori, detection tasks should be the paradigm of choice when assessing the visual functioning of very young observers (i.e., toddlers), and/or atypically developing populations (i.e., intellectually delayed, dyslexia, fragile-x syndrome, etc.) because of the different challenges, other than those related to perceptual functioning, that are often manifested in these populations. Specifically, we argue that potential confounding cognitive challenges, such as decreased working memory and attention, task comprehension, and left-right confusion, can be minimized using detection, rather than identification paradigms.

In conclusion, this study is the first to assess whether the choice of task paradigm (detection vs. identification) differentially affected visual performance on lower-level perceptual tasks as a function of age. In general, we found comparable performance across different stimulus conditions (static vs. dynamic; luminance- vs. texture-defined) and ages (school-aged through adulthood) when using either paradigm. Given their similar sensitivity to visual development, we suggest the use of detection paradigms when assessing visual abilities of very young and/or clinical populations as to avoid potential challenges not related to visual perception in these populations. Further research is needed to explore whether paradigm-contingent differences are manifested when assessing higher-level (cognitive) processes within a developmental context.

Acknowledgments

This work was supported by funding from a Fonds de la Recherche en Santé du Québec (FRSQ) doctoral scholarship (JH), a FRSQ Vision Research Network graduate scholarship award (AP), a CIHR-Canada Research Chair (Tier 1) in Developmental Neuroscience & Education (KC), and an NSERC discovery grant to (AB). We would like to thank the two anonymous reviewers for their comments, and Dr. Karen Dobkins for her insightful thoughts on the manuscript.

Commercial relationships: none.

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