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Can Art Change the Way We See?

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Abstract

Visual art is pervasive in modern society. From advertising to fine arts galleries, this medium plays a visible role in how we view and understand the world. In this review, we consider research that speaks to whether our experiences with art can change the way we see. Numerous studies speak, often indirectly, to this question—addressing whether artists see things differently from non-artists. Specifically, we reviewed literature that investigates the ways artistic ability and artistic training interact with visual abilities from the perspective that artists can be described as experts in visual media. Some work suggests that those who identify as artists or undergo artistic training perform better than non-artists on measures of low-level vision, high-level perception, and visual cognition, and show differences in brain activity while engaged in perceptual or artistic tasks. Other studies do not support these conclusions, however, and report no differences between artists and non-artists. We conclude that experimentally designed and well controlled training studies are necessary to elucidate whether artistic training shapes the brain and its perceptual and cognitive processes or whether budding artists gravitate towards the visual arts because of existing visual abilities.

Keywords: vision, perception, expertise, visual arts, artist, artistic training

The history of human progress is to a great extent one of specialization. In almost every field of human endeavor—sports, medicine, music, or visual arts—we see individuals who aspire to, train for, or simply demonstrate expert levels of performance. There is a growing interest in the study of such expertise (e.g., the recently created *Journal of Expertise*), which requires a combination of approaches to understand more general individual differences as well as the mechanisms involved in the development of expertise. Expertise research is broad, extending from behavioral measurements to neural and genetic approaches, in domains ranging from chess to math to music (Hambrick, Campitelli & MacNamara, 2017).

One subfield of expertise research focused on expertise for visually recognizing objects like birds or cars (Tanaka & Taylor, 1991; Bukach, Gauthier & Tarr; 2006; Shen, Mack & Palmeri, 2014) has spawned interest in characterizing individual differences in object recognition (McGugin et al., 2012; Ćepulić, Wilhelm, Sommer, & Hildebrandt, 2018). Recent efforts to investigate such individual differences has used a latent variable framework to find evidence of a domain-general ability, distinct from general intelligence, which accounts for more than 85% of the variance in performance on a variety of tasks and categories of novel objects (Richler et al., 2019). The same ability can account for recognition of both novel and familiar objects, and neural correlates of this ability are distributed in several areas within the visual system (Sunday, 2019). It remains unknown what genetic and environmental factors influence this domain-general visual ability. Twin studies of domain-specific visual abilities suggest that such abilities have heritable components (around 50%, for the heritability of at least two domains of object recognition: faces and cars; Shakeshaft & Plomin, 2015), but variance that could also be environmentally influenced. Thus, it seems likely that the domain-general ability first reported in Richler et al. (2019) can be impacted by environmental factors. The extent of this influence and what kinds of visual experience can affect domain-general visual ability is an open question. One possible source of variability may come from appreciating and producing visual art. Indeed, it has been suggested that artists are "experts in visual cognition" (Kozbelt, 2001).

We were therefore interested in reviewing research that could address our primary question of *whether experience with visual art can improve general visual abilities*. Such evidence would ideally come from experiments that randomly assign individuals to art training vs. a control training and assess the effects of training on a variety of visual tasks. However, when reviewing the literature, the bulk of the research we found was of a correlational nature, asking a different, albeit related, question: *do visual artists and non-artists show differences in visual perception?* As we were guided by the research we found, it became clear that one of the most productive lines of research in this field has focused on questions aimed at *explaining the sources of errors in realistic drawing performance*, for instance asking whether performance on tests of perceptual constancy predict drawing accuracy (for a recent review, see Chamberlain, 2018).

While these three questions are related, they are clearly different. Artists could have superior visual perceptual abilities that do not necessarily translate into drawing skills or individuals with superior visual abilities could self-select into artistic fields. In the absence of experimental evidence speaking to the causal role of visual art training, we focus our review on potential evidence for superior visual abilities in artists. As outsiders to the study of art, we decided to focus on the strength of empirical evidence and what might limit it, without delving into the various theoretical frameworks that have been proposed regarding arts training and arts expertise (for recent reviews that include such discussions, see Chamberlain, 2018, and Kozbelt & Ostrofsky, 2018). Later in this review, we address challenges in evaluating whether any potential advantage for artists is domain-general, which may suggest a plausible means for training in visual art to affect how we see the world. If artists' visual advantage results from training and is found to generalize outside of art, art training might prove useful in other fields that rely heavily on visual skills (e.g., radiology, homeland security, geospatial analysis).

All of these questions are relatively unexplored at the moment, and complicated by the fact that vision is a highly complex process. Thus, we must consider the many components of vision that could be influenced by experience with art—from low-level visual abilities such as acuity and edge detection, to higher-level skills like object recognition and visual memory. Experience in visually recognizing and identifying objects can produce changes in visual perceptual strategies (Gauthier & Tarr, 1997; Gauthier et al., 2000; Chua & Gauthier, 2016; Wong et al., 2009; McKone et al., 2007). Given this, it is certainly possible that "experts" in art (e.g., art students, long-time artists, art historians, or art museum curators) have similar visual advantages when perceiving works of art. But effects observed in training studies in the perceptual expertise literature tend to be highly specific to the trained domain. So any advantages afforded by art training may be specific to art.

To locate relevant evidence, we searched through the existing published literature using terms such as "artist, memory", "artist, attention", "art training", "art perception", "art and category learning", and "artists vs. non-artist". Our initial search yielded 66 relevant papers from journals on cognition, perception, and art. Feedback from reviewers pointed to a few additional articles we missed during our initial search. We included studies that had pre- and post-test experimental training designs as well as papers measuring behavioral and neural differences between self-reported art experts and non-experts. We excluded studies in which none of the dependent variables were perceptual (e.g., studies comparing differences in drawing ability between artists and non-artists that did not also measure visual perception) or in which there was no non-artist control group[1] or that measured artistic skills only in non-artists[2]. Based on this extensive (although perhaps not comprehensive) sample, we organized our review according to the most frequent and relevant general topics. In doing so, we hope to facilitate interactions between research on visual arts expertise and the growing interest in how to measure individual differences in visual cognition.

A great deal of the relevant research we found focuses on ability and experience in representational drawing or drawing realistically. This is only one kind of visual art. Experience with abstract painting, photography, or studying art history could affect the manner in which one sees the world. There are practical reasons why past research has focused on representational drawing. The scientific study of expertise benefits from characterizing individuals' abilities on a continuous scale. For example, in studying perceptual expertise with birds or cars, researchers do not simply categorize individuals as experts because they know more names of birds or cars, but instead measure

[1] For example, Chamberlain et al. (2019) followed art students over 5 months in a drawing course. While this research identified changes over time, it is difficult to attribute these changes to the training itself vs. a selection-maturation interaction.

[2] For example, Ostrofsky et al. (2014) designed a procedure to objectively score the accuracy of portraits by non-artists and reported evidence that those who drew more accurately displayed a general perceptual encoding advantage.

individuals' performance on perceptual discrimination tasks that do not require semantic knowledge (e.g., Gauthier, Tarr, Anderson, Skudlarski, & Gore, 1999). In a similar manner, performance in representational drawing can be scored on faithfulness and accuracy across the entire spectrum of artistic abilities, regardless of the individual's knowledge of the principles that might apply (e.g., it is possible to draw a faithful reproduction of an object without being able to discuss concepts like vanishing points). This is generally scored by expert ratings, which typically show good internal consistency across raters (e.g., Cohen & Jones, 2008; Ostrofsky et a., 2012), and in some cases have been shown to converge with more objective measures other than ratings (Ostrofsky et al., 2014).

One consequence of the emphasis on representational drawing is that the study of how art experience might influence how one sees has to a large extent focused on those processes that can explain drawing errors (Cohen & Bennet, 1997; Chamberlain, 2018). These are sometimes separated into low-level or "bottom-up" factors, such as the ability to ignore perceptual constancies that lead us to ignore changes in size, shape, or brightness in the retinal image of a familiar object when viewing conditions change (Thouless, 1932), and higher-level or "top-down" factors, such as the ability to select the best segments to include in a faithful tracing of an object (Kozbelt, Seidel, ElBassiouny, Mark, & Owen, 2010). If the emphasis was on another type of artistic activity, such as photography, where framing decisions to achieve a balanced or an interesting composition are particularly important, researchers might expect visual perception to be influenced in other ways (e.g., the ability to attend to multiple elements at once). We did not find research that systematically compares how different kinds of visual arts activities (drawing, photography, painting, sculpture) or other kinds of arts experience (art history) might influence how we see, so we simply acknowledge here the large influence of drawing in this field of research and come back to this topic in our later discussion to address potential limitations.

We begin our review by focusing on eye movement research, a potential locus of influence of art on visual processing that is less closely linked to artistic production and could therefore be more general across artistic activities than aspects more plausibly linked specifically to drawing experience.

Section 1: Eye Movement Differences Between Artists and Non-Artists

Eye movements when scanning an image can provide information about underlying visual processing, as eye movements are presumed to be a rough proxy for visual attention (Duchowski, 2002). Some research has specifically sought to describe the properties of eye movements during drawing that may relate to drawing accuracy. For instance, Cohen (2005) suggested that the frequency of switching gaze between the drawing and model predicts accuracy, but interestingly, this was true regardless of art training. Tchalenko (2009) found that experts have learned to divide the model into simple segments of near uniform curvature, resulting in better drawings (see also Glazek, 2012). In this sense, artists, while sketching, seem to use a more local strategy than novices.

Beyond drawing, we can also ask whether artists explore visual scenes differently. Several studies have found that artists tend to employ more “global” scanpaths, whereas novices employ more “local” scanpaths (Nodine, Locher, & Krupinski, 1993;

Zangemeister et al., 1995; Pihko et al., 2011). As one example, Zangemeister et al. (1995) defined eye movements of 1.6° of visual angle or less as "local" eye movements, and eye movements greater than 1.6° as "global" eye movements. When comparing how artists and non-artists view paintings, many studies found that artists fixate less than non-artists on critical regions of an image (usually visually salient figures or objects in each image). For example, Zangemeister et al. (1995) found that artists and "sophisticated" viewers, such as art gallery owners, used more global scanning than naïve viewers when looking at paintings, particularly abstract ones. But at least one study found no significant difference between scanpaths of artists and non-artists when viewing line drawings of geometric objects (Perdreau & Cavanagh, 2013).

Thus, it is possible that artists use more global scanning when looking at art or other complex scenes but are more local when sketching. One limitation of eye movements studies to infer the manner in which artists perceive images is that a global approach could be inferred from either eye movements that span a larger part of the image (suggesting the observer is more actively exploring) or from fewer eye movements (suggesting more information from the image can be obtained from individual fixations). Therefore, convergence with other measures (behavioral or neural) is critical.

Other eye movements studies have investigated the effects of image familiarity, task instructions, and stimulus category on eye-movement scanpaths as a function of art experience. One study found no scanpath differences between artists and non-artists when viewing familiar paintings but did find that artists had higher fixation densities within non-regions of interest (as defined by the researchers) than non-artists when viewing unfamiliar paintings (Kristjanson, Antes, & Kristjanson, 1989; Antes & Kristjanson, 1991). Related work by Vogt and Magnussen (2007) compared scanpaths of artists and non-artists while viewing a set of paintings that repeated across two sessions. Regardless of image repetition, artists were less likely than non-artists to focus on humans and recognizable objects and instead inspected more abstract or structural features of the compositions. Novices also showed a reduction of fixations for previously-viewed items, whereas artists showed the opposite pattern (more fixations for repeated items); this result in artists was unexpected (but only nine subjects were tested in each group).

Beyond asking whether art training affects the way images are scanned, researchers also noted the importance of the type of image on how it is scanned. Specifically, researchers have asked whether the level of abstraction of an art piece (e.g., realistic art like the Mona Lisa vs. highly abstract art like a Jackson Pollock work) influences eye movements, and whether this differs with art experience. Both artists and non-artists use more global scanning when viewing abstract art than when viewing representational art, according to Pihko et al. (2011). In contrast, Zangemeister et al. (1995) and Vogt and Magnussen (2007) only found this pattern (increased global scanning with increased abstraction) for artists, while viewing strategies by non-artists did not differ significantly based on the abstraction of the piece of art. What is encoded during these episodes and whether these eye-movement differences result in differences in perceptual performance was not measured. While some studies focusing on eye movement measures also report differences in behavioral performance on high-level perceptual tasks between groups (Vogt & Magnussen, 2007; Perdreau & Cavanagh, 2013; Glazek, 2012), no study has directly related eye movement patterns to specific behaviorally-measured perceptual advantages or disadvantages. Future work could better elucidate the behavioral ramifications of any observed differences in eye movements between experts and novices in art.

Another approach could be to measure eye movement differences between groups under different instructions. Are effects driven by long-term practice or by an explicit strategy adopted under explicit instruction? For example, Zangemeister et al. (1995) found that artists employed more global eye movements when given instructions to study artworks for a later memory test compared with when they freely scanned the art, whereas viewing strategies by non-artists did not change between instruction conditions. Such results narrow the conception that artists generally view the world differently than non-artists to instead suggest that artists may have a broader repertoire of attentional routines that can be deployed depending on current task goals.

Section 2: Visual Perceptual Differences Between Artists to Non-Artists

2A: Attention, Memory, and Object Recognition

While artists are expected to excel in what is broadly recognized as artistic ability, some may also excel specifically in the accuracy of their representational drawing (Chamberlain & Wagemans, 2015). When drawing, artists attend to different features of the object, focusing on line junctions that are critical features for recognition (Biederman & Kim, 2008; Ostrofsky, Kozbelt, & Seidel, 2012).

Differences between artists and non-artists may be in large part due to practice and instruction (Chamberlain, 2017) but artists' superior skills could also be observed because individuals having superior motor coordination, visual perception, memory, or attention self-select into art fields (Chamberlain, 2018). To fully tease apart these two causes would require experiments using random assignment, or at the least measuring perception, attention, memory, and the like before any art practice or art instruction; of course, that could be a practical challenge given that many people who become artists began taking additional art instruction when they are young. A more indirect approach lies in asking whether artists outperform non-artists in visual arenas other than those they have explicitly trained for. Accordingly, several studies have measured skills in object recognition, face recognition, and visual imagery to address this question (Pérez-Fabello & Campos, 2007; Glazek, 2012; Chamberlain & Wagemans, 2015; Devue & Barsics, 2016; Tree et al., 2017).

Based on a working hypothesis that creativity and mental imagery capacity are related, Pérez-Fabello and Campos (2007) found support for claims that artistic training improves mental imagery (Zemore, 1995; Morrison & Wallace, 2001). Fifth-year art students performed better on tests of mental imagery capacity (the Visual Elaboration Scale and the Vividness of Visual Imagery Test, both evaluated for reliability and validity) than first-year students (Pérez-Fabello & Campos, 2007). The fifth-year art students also had superior performance when asked to imagine and then draw various scenes, or to study a work of art and then draw it from memory. The researchers concluded that training in art improves mental imagery abilities (Pérez-Fabello and Campos, 2007). However, it remains unclear whether attrition from art school (e.g., students with poorer performances on these tests drop out of these programs before reaching their fifth year) or selection into art programs can account for some of the observed differences between groups.

In a later study, all participants completed visual imagination and motor imagination tests in which they rated their ability to imagine various scenes or motor tasks on a five-point scale (Kottlow et al., 2011). Artists scored better than non-artists on the visual imagination test, but no differences were found in motor imagination scores. On the drawing task, artists drew significantly more details than non-artists and were also more likely to begin their drawings with a detail, whereas non-artists more frequently began with perspective lines (e.g., the room structure or furniture depicted in the scene). These results are consistent with the idea that artists' visual imagination may be superior to that of non-artists. But they are also consistent with the idea that art training increases the ability to draw and attend to details, which may in turn enrich visual imagery. Interestingly, no differences were found between groups in the number of objects and scenes remembered after this drawing task (Kottlow et al., 2011).

In one study (Glazek, 2012), art experts showed a statistically marginal advantage ($p=.09$, one-tail test) on discriminating pairs of novel Chinese characters differing only in one extra stroke. The author interpreted this finding as evidence of a "visual-encoding advantage" for art experts. This is a tantalizing finding because subjects were tested in an untrained domain, but the results would need to be replicated and a more stringent statistical criterion enforced. In studies of perceptual expertise that have documented faster encoding and larger visual short-term memory capacity in car experts, the advantages are believed to be domain specific (for instance, car expertise does not generalize to inverted cars, Curby & Gauthier, 2009; Curby, Glazek & Gauthier, 2009).

Artists may possess advanced abilities for processing object structure that cannot be explained simply by general advantages in visual processing or visual acuity given that they are faster and more accurate at classifying line drawings of three-dimensional objects as possible or impossible (impossible because of too many lines converging at one corner, or an edge with no border; Perdreau and Cavanagh, 2014). Chamberlain and Wagemans (2015) found that drawing ability was related to both better local processing and enhanced global processing, as well as a better ability to flexibly switch between the two levels of processing. Being an art student also separately predicted better global processing and switching abilities. In a later study, art students outperformed controls on the Raven's visual matrices, a visual intelligence measure, an embedded figures task (even after controlling for performance on the Raven's), and a mental rotation task (Chamberlain et al., 2017), further suggesting that those with art experience and training show enhanced performance in certain aspects of high-level visual processing.

With regard to face recognition, there is conflicting evidence as to whether artists outperform non-artists. Devue and Barsics (2016) found that portrait artists were more accurate at facial discrimination and recognition—as well as object recognition and mental rotation—than non-artists. In contrast, Tree et al. (2017) found no differences between experimental subjects who completed a 1-year art course and control subjects or between portrait artists and controls on tests of face recognition ability. Similar face recognition ability between portrait artists and non-artists was also found by Zhou et al. (2012). Intriguingly, however, these researchers did find that these portrait artists showed reduced holistic processing of faces (the tendency of observers to pay obligatory attention to all parts of a face, with emphasis on spatial relationships among parts). More recently, a re-analysis and extension of the data originally presented in Devue and Barsics (2016) revealed that face recognition and visual short-term memory measures were related to portrait drawing ability in novices. This suggests that if artists possess better face recognition abilities than controls, it may reflect pre-existing advantages (Devue & Grimshaw, 2018). Interestingly, face recognition ability also predicted house drawing ability, which could mean that the pre-existing advantage in artists may not be specific to faces (Devue & Grimshaw, 2018). It should be pointed out that the work showing null effects (Tree et al., 2017 and Zhou et al., 2017) had much larger samples than the Devue & Barsics (2016) study, in addition to different tasks used to operationalize face recognition and discrimination.

2B: Low-Level Vision and Perception

While the studies discussed in the previous section investigated how experience with art, art training, or artistic ability relates to higher-order visual cognition processes, other studies have explored whether art experience relates to low-level visual perceptual processes. Given that creating art often requires artists to explicitly manipulate properties like color, shape, and contour, it is possible that artists have superior abilities to perceive elementary visual features or are simply more accustomed to attending to such low-level features based on their art training.

Several studies failed to find evidence that artists possess superior (or different) low-level visual abilities. An early study looked at the features that people use to detect abstract patterns (Washburn, 2000). Artists and non-artists both used color to distinguish the edges of negative space in colored patterns and contour in black-and-white images, suggesting that art experience does not affect the kinds of features used to discern shapes. A qualitative study found that figure-ground illusions and perception of color, contour, and boundary were pervasive across all participants regardless of age or experience with art (Pinna, 2011). Perdreau and Cavanagh (2011) found no evidence that years of art experience predicted the effect of visual context on perception. In fact, on tasks involving size and lightness contextual influences, increased artistic experience was actually related to slower response times, suggesting increased effort or care in accurately completing the task (Perdreau & Cavanagh, 2011). Another study measuring thresholds for perceptual grouping principles found no effect of self-reported art expertise (Ostrofsky, Kozbelt, & Kurylo, 2013). One study (Cohen & Jones, 2008) found that better drawing accuracy was related to performance in a shape constancy task, but no effect of formal art training was observed.

While Chamberlain et al. (2013) found performance on aspects of some visual perceptual tasks related to drawing ability, they found no difference between art students and controls on any perceptual tasks. Along these lines, although Chamberlain et al. (2019a) found better visuo-spatial ability in relatively high-level tasks (e.g., on disembedding figures) in art students compared to non-art students at an early point, before the art students started studying representational drawing, they found no advantage in tasks that measure relatively lower-level perceptual skills (e.g., resisting visual illusions). Art students did experience more reversals of a bistable figure than novices, and this could be a relatively low-level effect since they showed no better ability to control these reversals under instructions. When the same art students were followed over a period of five months during which they studied representational drawing, they were found to improve in their artistic and relatively high-level visual skills rather than low-level visual skills.

Other studies offer more mixed findings, reporting differences between artists and non-artists in some tasks and measures but not others. There is evidence that artists can outperform non-artists under some limited viewing conditions (e.g., when viewing objects through a small circular viewing "window" that moved with their eye scanpaths), but not under other limited viewing conditions (e.g., when an opaque mask or "scotoma" blocked part of the participants' view; Perdreau & Cavanagh, 2013). Artists also showed faster (but not more accurate) recognition of abstract stimuli presented to the left visual field (and thus processed by the right hemisphere first) than when presented to the right visual field, while art novices showed no such difference (Vogt and Magnussen, 2005).

In summary, while evidence supports the idea that artists may show perceptual advantages in certain high-level aspects of visual cognition, advantages are not observed in low-level aspects of visual perception (Kozbelt & Seeley, 2007; Kozbelt & Ostrofsky, 2018). There is, however, room for caveats that have to do with methodological challenges when group differences, individual differences, or even longitudinal differences are sought based on a large number of tasks that were not designed for this purpose.

2C: Considerations of Measurement

Many studies comparing artists to non-artists have few subjects per group—typically less than 20, often as few as 10. As in too many studies in psychology, the *a priori* power of the planned contrasts are almost never discussed (Ellis, 2010).

According to Uri Simonsohn (as reported in Mikulak, 2013), 20 people per group "would be enough to detect that men are, on average, taller than women and that people above the median age are closer to retirement. But it's not sufficient to detect that people who like spicy food tend to like Indian food, for example. It's not even sufficient to detect that men tend to weigh more than women, which requires about 46 people in each condition." Because absence of evidence is not evidence of absence, given the growing consensus that artists do not have better low-level visual skills than non-artists, it would be more appropriate to use Bayes factors to quantify actual support for null effects (e.g., Dienes, 2014).

In addition, most of the research dichotomizes artists vs. non-artists (and not always using the same definition[3]), a practice that limits power and often leads to misleading results (MacCallum, Zhang, Preacher, & Rucker, 2002). For example, one study (Kozbelt, 2001) found that first-year art students scored higher than novices on four tasks (out-of-focus pictures, Gestalt completion, embedded figures, and mental rotation) but no clear difference between first year and fourth-year art students were observed (more advanced students doing no better, worse, or better than first year students, depending on the task)..

Given that one's status as an artist may be hard to quantify outside of duration of formal training (but see Pang et al., 2012, for a reliable art expertise questionnaire), this may explain why many of the more systematic studies of art and perception have focused on predicting the accuracy of drawing, which can be conveniently quantified, even among non-artists. This practice is usually supported by very high interjudge reliability (often higher than .9) of the quality of a single copy, observational drawing, or portrait from each participant (or of the responses to several questions about that single drawing,

[3] This would not limit power, only consistency of results across different studies.

e.g., Chamberlain, 2019a). However, such reliability reflects the reliability of judgements of a set of drawings (say, all copies of the same model) rather than the reliability of individual subjects' drawing accuracy. For instance, in Chamberlain, (2019a), interjudge reliability for ratings of a single still life by 79 subjects was .95 (for non-artist judges), but the correlation in performance between two separate drawing tasks was only .67. While drawing ability is an interesting concept to study, it would be useful to increase domain coverage (for instance by collecting copies and drawings of different types of scenes, portraits, or patterns, to avoid variability coming from differential practice with one type of material) and to assess how much stable variance is present in these measurements. This is important to do before interpreting variability in drawing accuracy to performance on other tasks (because, if drawing accuracy of a portrait only moderately predicts accuracy of copying a still-life, it lowers expectations for how each of these tasks can correlate with a measure of susceptibility to visual illusions).

Beyond issues measuring drawing accuracy, there is a general concern with the reliability of tasks used in the studies in this field. First, reliability (outside of rating tasks) is almost never reported, but correlations are difficult to interpret without that information. There is a theoretical upper limit for the correlation between two tasks that is the geometric mean of the reliabilities for the two component tasks (Schmidt & Hunter, 1996). For example, Chamberlain et al., (2019a) found little to no correlation across a set of visuo-spatial tasks that were to be correlated with drawing accuracy, but the reliability for those tasks was not reported. It has been demonstrated that tasks that detect experimental effects within subjects with high sensitivity often show very little reliability with regards to between-subjects variance (Ross, Richler, & Gauthier, 2015; Hedge, Powell, & Sumner, 2018). Tasks that use difference scores (such as the Navon task, often used in this field) and/or response times are especially problematic (Draheim, Mashburn, Martin, & Engle, 2019). Tasks that use only a few trials, such as visual illusions tasks, may not be able to discriminate between individuals over the entire range of visual ability. Moreover, because correlations across different measures are limited by the reliability of the specific measurements (and not some abstract reliability for the task in general), studies reporting correlations across different tasks should always interpret these correlations in the context of the reliability of their actual measurements (Thompson, 1994). These issues are not specific to this area of study, but we believe it would be premature at the moment to conclude that artists do not have better low-level visual perceptual abilities until this hypothesis can be tested with sufficient power and with measurements of such abilities that have documented reliability. Poor reliability limits power, and low power inflates both Type I and Type II error rates, so these concerns affect the interpretation of both null results and positive findings, and may contribute to some of the inconsistencies observed across studies in the field.

2D: MRI, fMRI, and EEG Measures

Beyond behavioral differences between artists and non-artists, some studies have begun using approaches like magnetic resonance imaging (MRI and fMRI) and electroencephalography (EEG) to characterize neural differences between artists and non-artists. Unlike behavioral approaches, these neuroimaging methods can detect differences in the neural correlates supporting performance, even in cases where behavioral differences are not observed (e.g., Gauthier, Skudlarski, Gore, & Anderson, 2000). In addition, even if we are mistaken about the exact mechanisms that may differ between artists and non-artists (or how to measure these mechanisms behaviorally), neural measures of both activation and structure may detect differences, and may do so in an unexpected brain area (e.g., a difference could be observed in high-level visual areas in what is considered a low-level visual task).

One of the first studies to use MRI (Huettel, Song, & McCarthy, 2004) to explore the link between artistic experience and brain activity found lower activity levels in the right posterior parietal area of an artist as compared to a control when sketching faces, which was interpreted as evidence of more efficient visual face processing (Solso, 2001). Critically, however, this work tested only one artist and one control. This work exemplifies the early enthusiasm of psychologists for neuroimaging, but neuroimaging is no different from behavioral measures in showing a great deal of individual differences across people, and requiring reliable measurements (McGugin & Gauthier, 2016). It is impossible to interpret a difference between two people as reflecting their experience or talent with art as opposed to this difference simply representing normal variability.

Later work extended and improved on this early work. Long et al. (2011) found greater gray matter density in the left fusiform of a group of painting majors relative to a control group. In a different study, drawing ability was correlated with grey matter density in the left anterior cerebellar cortex and right supplementary motor cortex, whereas the only difference for art students vs. controls was in the right precuneus (Chamberlain et al., 2014). This study did not find any differences in occipital cortex, which supports early to mid-level visual processing. However, research pointing to how cortical thickness in a specific part of the occipito-temporal cortex correlates with face and object recognition ability found that the result depended on using a definition of a face-selective functional region of interest (McGugin et al., 2016). In other words, because neural effects can align based on function rather than anatomy, null results can be especially hard to interpret. Whether these structural differences exist before training (i.e., reflect why an individual might be interested in art training) or arise during training remains unknown.

To better control for pre-training differences, one group of researchers conducted a training study using both behavioral and fMRI measures to compare behavioral and neural effects in a control group and a group of students completing an eleven-week drawing and painting course (Schlegel et al., 2015). Unfortunately, while participants taking the art course were not originally art students, they were not randomly assigned to experimental and control groups, and thus classical subject selection concerns (Campbell & Stanley, 1996) cloud interpretability. No difference in perceptual skill was observed between groups, although drawing abilities improved with explicit training. However, a linear classifier (also known as multi-voxel pattern analysis or MVPA) was better able to distinguish between whole-brain activity patterns collected during a drawing task between groups as the painting course progressed (Schlegel et al., 2015).

Another study found that during a color naming task, painting majors showed more activation than controls in V4, a color-selective area, and this activation correlated with that in the left ventral lateral prefrontal cortex. Interestingly, there were no group differences in activation during passive viewing of colors (Long et al., 2011). Given that the researchers also found reduced activity in artists' Broca's areas, an area associated with speech production, relative to controls during the color naming task, the differences observed could be strategic and due to the painting majors' greater experience naming ambiguous colors (the colors were generated randomly and painting majors generated more distinctive names for them). Although it is always difficult to rule out the possibility that functional differences are due to differences between groups in their motivation, attention, or task difficulty, later work has shown task-specific categorical clustering for color in V4 (Brouwer & Heeger, 2013), so Long et al.'s results could reflect a change in categorical perception associated with explicit art training. Thus, the MRI studies reviewed here suggest possible task-specific functional changes in occipital areas, but also structural changes both in that same occipital area (V4) and in cortical regions associated with motor skill learning (e.g., the cerebellum).

In addition to MRI, researchers have used EEG measures to examine differences in cortical activity between artists and non-artists when viewing art. Gamma, beta, and delta phase synchrony (when multiple frequency bands oscillate in sync with one another) played a significant role in perception for artists as compared with non-artists in a study by Bhattacharya and Petsche (2002). Since interactions in high frequency bands were hypothesized by the authors to be related to bottom-up processing, they interpreted this difference as evidence of artists' ability to bind visual features. In contrast, they found enhanced phase synchrony from the alpha band upwards in non-artists, which the authors attributed to the more random and less broad viewing patterns of non-artists as compared to artists. Pang et al. (2012) found a negative correlation between the score on an art expertise questionnaire and event-related potential (ERP) amplitude, revealing that greater art expertise was associated with lower electro-cortical amplitude in bilateral parieto-occipital regions. This was true for images of paintings, for images of paintings with a blurring filter applied, but also for single-color swatches. While the differences based on art expertise again indicate a relationship between less brain activity and greater expertise, the lack of discrimination of amplitudes when viewing the three different stimulus types even among artists provides evidence for changes than may go beyond domain-specific strategies, suggesting that art experience could affect the processing of all visual stimuli.

Although Pang et al. did not find differences in ERPs based on the type of visual stimulus being viewed, other research has reported differences based on material or based on task. Batt et al. (2010) found higher alpha band synchrony in non-artists than artists for abstract art, which the authors stated could be reflective of the alpha band's relation to top-down control (i.e., novices might judge abstract art based on meaning rather than on visual details). Conversely, higher theta synchrony in artists for abstract art might be associated with their sustained attention and interest in abstract art. These results support the hypothesis that artists' cortical activity reflects their perceptual flexibility and sustained attention, while non-artists' cortical activity indicates their engagement with the task. Another group investigated EEG differences between groups while engaged in different tasks (Kottlow et al., 2011). Differences in cortical activity were found while participants engaged in the activities related to drawing and imagining, but not in motor and perception control tasks (scribbling and passive picture viewing, respectively), indicating something specific about brain activity during the creation of art. A reduction in alpha power (found for artists but not non-artists during the drawing and imagining tasks) may reflect better visual discrimination, spatial attention, and semantic memory in artists (Kottlow et al., 2011)

Overall, the MRI and EEG results suggest there might be differences in brain activity between artists and non-artists when viewing art or other visual stimuli, although most research suggests that the observed differences are related to the variation in levels of experience with art, rather than differences related to perceptual abilities (the exception may be color perception). Some of the work only finds differences in brain activity between groups when participants are engaged in drawing tasks rather than passive viewing of art, suggesting such differences might reflect decreased effort in the artists during practiced activities. Questions regarding whether motivation or attention can account for expertise effects in visual areas are not specific to the art domain (see Harel, Ullman, Harari, & Bentin, 2011). Arguments against these claims have been based on studies where the tasks are too easy to elicit performance differences (Gauthier et al., 2000) and studying the robustness of effects under varying perceptual and attentional load (Williams McGugin, Van Gulick, Tamber-Rosenau, Ross, & Gauthier, 2015). Importantly, structural effects cannot be explained task-relevant effects such as motivation or attention.

As for behavioral effects, to determine whether observed differences are due to art training, a training study comparing subjects randomly assigned to an art training vs. a control training would be needed. Schlegel et al.'s 2015 study comes closest, but students self-selected into art training and were not randomly assigned. Even when baseline measures are reported to show equivalence on some or even many dimensions before training, self-selection on some unmeasured variable of importance means that changes during training without random assignment are difficult to confidently attribute to the effect of art training per se.

Section 3: Educational Applications

3A: Primary and Secondary Education

Research has examined whether arts education might enhance abilities in other academic areas beyond the arts. It is possible that operations performed when creating art (e.g., mental manipulation of shapes, translating 3-D images into 2-D representations) engage mechanisms that also underlie skills used in an academic setting (e.g. visuo-spatial skills used for geometry, mental imagery, geography, and geology). Can improving these mechanisms through art training improve academic performance in other areas?

A meta-analysis of thirteen studies evaluating the effect of art training on reading skills in young children (Burger and Winner, 2000) found a modest but complicated effect. Reading is a visual activity engaging visual brain areas, among others, and an effect of art training on reading would reflect a domain-general influence of the arts. A small positive relation between participation in programs that incorporated art into the reading curriculum and reading ability was observed—but only for studies in which the reading ability measure was a reading readiness test (which is visual in nature) rather than a reading achievement test (which is far more linguistic). Perhaps most problematic, the experimental group in all studies in this meta-analysis confounded additional reading instruction along with arts instruction relative to what the students received in the regular reading curriculum.

Another study explored the connection between visual arts training (as compared with theatre training) and visual-spatial-geometric skills in high school students

(Goldsmith et al., 2016). In addition to performing better than theatre students on a geometry test both before and after training, art students showed greater growth and improvement in their geometry scores from pre-test to post-test (Goldsmith et al, 2016). Though these results suggest that art training may impact mathematical performance, it is important to emphasize that students in the visual arts condition self-selected into this group and that they outperformed the students in the theatre condition on the geometry test at pre-test as well as post-test; these students had a propensity to benefit from art training. Indeed, another study found that nonverbal IQ was higher in a group of self-selected art students relative to control students (Chamberlain et al., 2019a).

In addition to reading and spatial skills, research has also examined whether studying the arts can improve students' Scholastic Achievement Test (SAT) scores; politicians and educators have often made this assertion based on questionnaires filled out by students taking the SAT. Vaughn and Winner (2000) dug deeper into this questionnaire data and found that beyond the relation between self-reported years of arts experience and SAT scores, many other variables could account for the effect. For example, students who chose to study the arts might be high-achieving students to begin with, or perhaps schools that offered art programs also have stronger academic programs. Years of study in academic courses (e.g., math, foreign language) was in fact a stronger predictor of SAT scores than years of study in art courses.

Overall, while a direct link between studying art and cognitive abilities or test scores is weak at best, there does seem to be a link between studying the arts and performing better in other academic areas, if only because of engagement and motivation, or even to pre-existing differences in non-verbal intelligence (as in Chamberlain et al., 2019a). One way to minimize selection effects (Campbell & Stanley, 1996) would be to study children (or novice adults) who are trained in art based on random assignment into art classes or conduct longitudinal studies when there are requirements for children of a certain age to engage in art curriculum, regardless of their natural abilities or interests.

3B: Medical School *and the Arts*

Diagnosing patients in many medical specialties involves visual observation—whether of the actual patient, histology slides, x-rays, MRIs, etc. There has been some interest in asking whether visual art training might impact such clinically-relevant visual skills. Early studies hinted at a connection between clinical skills and performance in visual tasks unrelated to art (Nodine & Krupinski, 1998; Manning et al., 2006). One recent study applied visual perception training developed for basic research on perceptual expertise (Gauthier, Williams, Tarr, & Tanaka, 1998) to training of the visual identification of skin cancers (melanoma) and found that participants who completed perceptual-expertise-based training in melanoma detection were better able to detect melanoma and employed a more conservative decision criterion than the control participants who received no training (Xu et al., 2016).

It is possible that a link may exist between visual artistic skills and clinical skills. Various visual art training programs have been added to both undergraduate pre-medical and medical school programs. Several studies have examined whether such training can improve clinically-relevant diagnostic skills, and found some modest evidence of success (Bardes, Gillers and Herman, 2001; Dolev, Friedlander and Braverman, 2001; Shapiro, Rucker and Beck, 2006; Nagshineh et al., 2008). Medical students trained to visually observe art may improve their visual diagnostic skills in general (Bardes, Gillers and Herman, 2001; Dolev, Friedlander and Braverman, 2001; Nagshineh et al., 2008; Shapiro, Rucker and Beck, 2006). Bardes et al. (2001) found that training with Western portrait art administered by art educators improved clinical descriptions by students, such that they described a patient with more detail and inferred more about the patient's emotional and physical condition. However, other research, using a longitudinal approach, found it difficult to conclude that their art-training program was effective, but improvements in some years suggested possible benefits of art intervention for medical students (Dolev, Friedlander, and Braverman, 2001). Shapiro, Rucker and Beck (2006) found that students in both the art training and traditional clinical training improved their observational skills and pattern recognition, but that the clinical students developed further in these skills as it related to medical assessment and diagnosis, while the art group instead developed more in the areas of emotional recognition, empathy, and awareness of multiple perspectives. The number of observations made about patient photos and art images has been found to increase with art training (Nagshineh et al., 2008); in this study, art training resulted in more use of fine arts concepts to describe the images, specifically mentioning things such as color, shadow/light, symmetry, and the like.

Overall, these programs suggest, albeit with modest evidence, that the viewing and discussing fine art might encourage medical students to be both more observant and descriptive of visual details, which may or may not be associated with improved general visual perceptual abilities. Based on studies of wine expertise that have reported evidence that superior performance by wine experts derives more from conceptual knowledge and verbal labeling rather than from any superior perceptual ability (Hughson & Boakes, 2002; Ballester et al., 2008), it is possible that the improvements seen in medical students with art training results from similar improvements in semantic knowledge of relevant visual labels rather than improvements in visual perceptual skills.

Section 4: Relations to Recent Progress on Visual Individual Differences

We set out to explore whether there is published evidence that training to appreciate or produce art can change the way we see the world. We found little evidence that speaks directly to this question, for two reasons.

The first is that the vast majority of the published work uses one of several correlational approaches, where extant artists are compared to controls or where measures of cognitive or perceptual abilities or measures of neural activity are correlated with self-reports or, more commonly, measures of drawing accuracy. Even the few longitudinal studies assessing training effects are too often limited by classic subject selection concerns with a lack of random assignment to training conditions.

The second, more subtle reason is that studies often attempt to draw fairly general conclusions, for instance, about changes to "perceptual abilities", from performance on a set of specific tasks without strong evidence that these tasks all tap into a common, coherent "perceptual" factor. As one example from some of the strongest work in the field, Chamberlain (2019a) used a range of tasks thought to tap into higher-level perceptual processes (such as mental rotation, disembedding figures from a complex display, identifying blurry images) and lower-level perceptual processes (such as visual illusions, switching between bistable percepts). The statistical relationships between measurements of task performance did not clearly support such groupings into high-level and lower-level processes, which the authors acknowledged, citing the "multifarious nature of visual processing". Some of the low correlations between tasks are likely due to low reliability (reliability was not reported); closely-related perceptual measures showed only small correlations (e.g., correlations between three visual illusion tasks ranged from .08 to .26). Even when single measurements achieve good reliability, when they show a limited correlation with measures of drawing accuracy, it is important to remember how difficult it is simply to find a correlation between two measures of visuo-spatial skills. In other words, any field that aims to study a possible link between two relatively distal constructs (e.g., drawing skills and visuo-spatial skills) needs to first address the challenge of developing convergent measurements of each of these constructs.

A productive individual difference approach requires going beyond documenting variation across individuals on some number of tasks or looking for correlations or group differences. Variability in performance on any task is a combination of variability on the psychological construct of interest, variability specific to the task or the stimuli (test-retest reliability is typically lower between different test forms than for the same test form), and variability specific to the state of the participant during testing (test-retest reliability across sessions is typically lower than split-half reliability within the same session), and, additionally, measurement error. When looking to cross the bridge between art and perception, the chief source of variance of interest should be variability on the construct of interest, with demonstrated stability over specific tasks, specific stimuli, and over time.

A latent-variable framework is a powerful statistical approach to identify such variability, by measuring the shared variance of several indicators for a construct of interest. This has been productive in the area of high-level vision, for instance in measuring latent factors associated with face recognition based on different tasks (Hildebrandt, Wilhelm, Herzmann, & Sommer, 2013, Ćepulić et al., 2018) or, more recently, a visual object recognition ability, *o*, accounting for performance across different tasks (e.g., recognition, matching, and even ensemble judgments) and categories of objects (both familiar and novel; Richler et al, 2019; Sunday, 2019). Such a domain-general factor as *o* is ripe for exploration of relations to other domains and could be used in future art-related studies. The tasks that tap into *o* require efficient encoding and manipulation of the visual representations of complex objects and the ability to find the features or dimensions that are critical for their individuation. The kind of deliberate attention to both details and global organization that is typical of art training could plausibly be related to such abilities. In recent studies, this visual object recognition ability was related to medical image decision making (Trueblood et al., 2018), even after controlling for intelligence (Sunday, Donnelly, & Gauthier, 2018).

Conclusions

Although interest in art varies between individuals, its potential importance to society as a whole extends beyond museums to advertising, architecture, web design, etc. This review considered evidence that artists may see the world differently as a first step to asking whether experience with art could improve visual perception. Most of the relevant research focused on drawing, studying individuals who self-selected to study drawing, who have training in drawing, or who demonstrate good drawing skills in a specific task and comparing them to control subjects. Our survey of the literature converges with recent reviews to suggest evidence that artists may outperform non-artists in some high-level perception, visual cognition, or knowledge-driven processing but there is limited evidence for a difference in low-level perception (Kozbelt & Ostrosfky, 2018; Chamberlain, 2019b). However, we identified some limitations in measurement that may limit the strength of these conclusions. Research on this topic has improved greatly in recent years, with large sample sizes, comparisons of subjective and objective measures, controlling for general intelligence, and the inclusion of neural measurements. Future efforts should consider power analyses, explicit reporting of measurement reliability, and the use of methods that can better isolate variance related to constructs of interest. Recent work on individual differences in object recognition, which borrows measurement and analytical methods from fields with a long psychometric tradition, could provide avenues for fruitful exploration.

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