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Research Article

Functional near-infrared spectroscopy assessment of reward perception based on visual self-expression: Coloring, doodling, and free drawing

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ABSTRACT

Visual self-expression helps with attention and improves health and well-being. Few studies have examined reward pathway activation during different visual art tasks. This pilot study is the first to examine brain activation via functional near-infrared spectroscopy (fNIRS) during three distinct drawing tasks—coloring, doodling, and free drawing. Participants (11 men, 15 women; 8 artists, 16 non-artists) engaged in each task separated by equal intervals of rest in a block design experimental protocol. Additional data included a pre- and post survey of self-perceptions of creativity, prior experience with drawing tasks, and reflections on study participation. Overall, the three visual arts tasks resulted in significant activation of the medial prefrontal cortex compared to the rest conditions. The doodling condition resulted in maximum activation of the medial prefrontal cortex compared to coloring and free drawing; however, differences between the drawing conditions were not statistically significant. Emergent differences were seen between artists and non-artists for coloring and doodling. All three visual self-expression tasks activated the medial prefrontal cortex, indicating potential clinical applications of reward perception through art making. Participants improved in their self-perceptions of problem solving and having good ideas. Participants found the drawing tasks relaxing but wanted more time per task. Further study with varied art media and longer time on tasks are needed to determine potential interactions between participants' backgrounds and reward activation.

Introduction and background

Researchers have been exploring the ways that the experience of viewing and making art affect different parts of the brain. These studies have been made possible by making use of modern technology that identifies brain activity in different locations. Our study used functional near-infrared spectroscopy (fNIRS) to identify brain activity during varied self-expressions of visual art.

Visual art and the brain

Visual forms of self-expression, such as coloring books, are becoming increasingly popular among adults. Little is known, however, about the differences in brain activation and the perceived rewards of engaging visual expression. This study sought to examine differences in brain activation during different drawing activities measured with fNIRS. Although there are currently no fNIRS studies that examine activation during visual expression, there are a number of investigations that have demonstrated the activation of the prefrontal cortex during visual arts activities using other technologies. For example, Chamberlain et al. (2014) used magnetic resonance imaging (MRI) scanning to study the brain regions associated with drawing skills and artistic training. Their findings suggested that being able to draw from observation was associated with an increase in gray matter density in the left anterior cerebellum and the right medial frontal gyrus in the prefrontal cortex. Schlegel et al. (2015) showed that 3 months of art training resulted in changes in prefrontal white matter. Bolwerk, Mack-Andrick, Lang, Dörfler, and Maihöfner (2014) found that there was a clear difference between producing art compared to viewing art. Visual art production has been shown to improve the functional connectivity in several brain areas, particularly between the parietal and frontal cortices, as well as psychological resistance to change (Bolwerk et al., 2014). In their recent study, Miall, Nam, and

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Tchalenko (2014) explored the neural systems engaged in decision making related to drawing observed pictures. Ventral and lateral occipital areas were increasingly activated when participants were drawing faces rather than drawing abstract objects (Miall et al., 2014).

Although these findings suggest that visual art production results in stronger brain connectivity than cognitive art evaluation or viewing art, there is evidence that even passive engagement in art affects the prefrontal cortex (Bolwerk et al., 2014). For example, when viewing art, a reward circuitry is engaged that activates the ventral striatum, including the nucleus accumbens, along with the interconnected medial prefrontal cortex (mPFC) and the orbitofrontal cortex and amygdala (Lacey et al., 2011). Using functional MRI (fMRI) technology, Lacey et al. (2011) found that art imagery alone activated the reward circuitry whereas matched nonart images did not. Likewise, activation of the mPFC, along with the rest of the reward circuitry, occurred while the individual was viewing beautiful visual images or architectural spaces (Chatterjee & Vartanian, 2014). Comparing the brain activity of participants who were emotionally primed with portrait art with those who were not, Baeken et al. (2012) used fMRI and found that the former displayed higher activity in the left midline superior frontal cortex, whereas the latter showed higher right medial frontal cortical activity.

There are no studies on fNIRS and art-making but some exploratory studies have examined patterns in electroencephalogram (EEG) recordings and drawing. Belkofer, Van Hecke, and Konopka (2014) investigated the differences in patterns of brain activity among artists and non-artists during the process of drawing. Results indicated that there was more activity in the left hemisphere of the brain for artists, and more activity reflected in the frontal lobe for non-artists. This result may have been based on the fact that drawing was a new task for them and that stimulation in this area of the brain is a sign of learning. There was an increased presence of alpha waves for both the artists and the non-artists, indicating potentially relaxed creative opportunities generated by drawing tasks. Similarly, in a quantitative electroencephalographic comparison of clay and drawing, activation was noted related to regions of memory processes, meditative states, and spatiotemporal processing (Kruk, Aravich, Deaver, & deBeus, 2014). Art therapy researchers have also focused on the relationship between art and mood states. For instance, art-making has been found to reduce cortisol levels (Kaimal, Ray, & Muniz, 2016) as well as improve mood and self-efficacy (Kaimal & Ray, 2017). In addition, a number of studies have shown the benefits of coloring inside a shape, specifically a predrawn mandala, over free-form coloring (Curry & Kasser, 2005; Drake, Searight, & Olson-Pupek, 2014; Van der Vennet & Serice, 2012). Babouchkina and Robbins (2015) also observed that coloring inside a mandala was more effective in mood enhancement than coloring in a square. Comparing coloring to drawing, Smolarski, Leone, and Robbins (2015) reported that college students who were prompted to draw a positive expression ('something that made them happy', p. 199) had considerably more mood enhancement than when asked to draw their current feeling of stress (i.e., vent or trace a coloring book drawing). Andrade (2010) examined the outcomes of doodling on attention, demonstrating that it was beneficial in recalling information and monitoring tasks. Schott (2011) deduced from Andrade's study that, in some contexts, doodling may trigger an arousal and then stabilize it at an optimal level by reducing boredom and daydreaming.

Functional near-infrared spectroscopy

A noninvasive, safe, and portable imaging method, fNIRS detects blood flow activity in the human prefrontal cortex. This technique was pioneered in 1977 when it was demonstrated that photon transmission in the near-infrared spectrum (650–950 nm) could be used to screen hemoglobin concentrations and oxygenation in the brain (Jöbsis, 1977). Since then, and especially within the last 10 years, fNIRS has emerged as a viable neuroimaging tool, used to monitor neural activity in response to cognitive tasks, motor tasks, stimuli, and language processing (Ayaz et al., 2013; Ferrari & Quaresima, 2012). The typical fNIRS unit is composed of light sources and photodetectors mounted on a flexible sensor band that can be worn as a headpiece. The light sources are made up of either light-emitting diodes (LEDs) or fiberoptic bundles (Irani, Platek, Bunce, Ruocco, & Chute, 2007). Other parts of the equipment include a control box for hardware organization and a computer for data acquisition (Ayaz et al., 2012). Baseline measurements are taken, followed by continuous, real-time measurements at predetermined time intervals. Although there are a variety of possible placements, the near-infrared light is most commonly placed over the scalp to measure tissue oxygenation changes in the outer cortex regions (e.g., the motor or the prefrontal cortex; Izzetoglu et al., 2011). fNIRS uses near-infrared light with spectroscopy principles. Hemoglobin, the oxygen carrier in red blood cells, presents a differential absorption in the near-infrared wavelengths based on whether it is bonded to the oxygen. The optical window of the near-infrared spectrum, on the other hand, allows for light to penetrate several centimeters through the tissue due to the low absorption of main chromophores such as water and allows detection of the changes in concentration of oxygenated and deoxygenated hemoglobin molecules (Ayaz et al., 2013, 2011; Ferrari & Quaresima, 2012; Izzetoglu et al., 2011). In other words, hemoglobin absorbs light at different specific wavelength portions of the NIR spectrum, depending on how much oxygen it is transporting. Cerebral hemodynamic changes are associated with functional brain activity through a process termed neurovascular coupling (Ayaz et al., 2006).

Although fMRI has become the 'gold standard for in vivo imaging of the human brain' (Cui, Bray, Bryant, Glover, & Reiss, 2010), fNIRS has the advantage of being usable and adaptable to measuring brain responses to activities while the activities are occurring, either in the natural environment or under everyday field conditions. Thus, fNIRS is not limited to hospital, clinical, or laboratory settings. Additionally, fNIRS is minimally intrusive and more affordable than the former. Studies have shown that fNIRS signals are often highly correlated with fMRI measurements because both measure the hemodynamic response. Researchers have concluded that fNIRS can be an appropriate compliment to, if not a substitute for, fMRI, especially regarding brain activity related to cognitive tasks (Cui et al., 2010; Ferrari & Quaresima, 2012; Irani et al., 2007). In addition, fNIRS measurements have been shown to be complementary with the event-related EEG potentials (Ehlis et al., 2009; Herrmann et al., 2008). Research using fNIRS spans a wide range of disciplines, topics, and populations. It has been applied in neurology, psychiatry, education, and basic research (Ayaz et al., 2014; Izzetoglu et al., 2011; Ruocco et al., 2016; Teo et al., 2016). fNIRS has been used to examine people with varied conditions (e.g., Alzheimer disease, mood disorders, schizophrenia) and varied behaviors (e.g., language, memory, perception, sleep, pain; Ferrari & Quaresima, 2012).

Reward perceptions pathway in the prefrontal cortex

Though it is clear that the prefrontal cortex is related to higher order cognitive functioning (e.g., regulating our thoughts, actions, and emotions), it is less clear which area of the prefrontal cortex is responsible for different functions and whether there is even a systematic organization across the prefrontal cortex (O'Reilly, 2010; Ramnani & Owen, 2004). The brain is a complex network with functionally linked regions that share information continuously with each other (Van Den Heuvel & Pol, 2010). Generally, lateral prefrontal cortex areas seem to be involved in sensory, motor, and cognitive processing, whereas mPFC areas play a role in emotional, affective, and motivational systems (O'Reilly, 2010) and are part of the reward circuit (Chatterjee & Vartanian, 2014; Lacey et al., 2011; Russo & Nestler, 2013). The mPFC has been found to be widely connected to the amygdala, the nucleus accumbens, the hypothalamus, and temporal visual association areas and is involved in higher-order sensory processing and regulating emotional responses and somatic states (Arnsten, 2009; Damasio, Everitt, & Bishop, 1996; Wood & Grafman, 2003). The mPFC region has been associated with social cognition, long-term memory processing, and emotional processing (Euston, Gruber, & McNaughton, 2012; Grossmann, 2013). In addition, the mPFC, along with the perigenual anterior cingulate cortex and the dorsal anterior cingulate cortex, has also been implicated in an inferential track that is thought to select and learn actions that maximize reward (Donoso, Collins, & Koechlin, 2014). fNIRS has been used successfully for assessment of reward networks in prefrontal areas, particularly in substance abuse research (Bunce et al., 2012, 2013; Huhn et al., 2016).

The aim of our study was to assess reward perception by measuring the mPFC response during execution of three forms of visual self-expression. The main hypothesis guiding the study was that the free-drawing form of self-expression would evoke the most reward activation compared to the other two forms—coloring and doodling. We also hypothesized that the reward activation would be greater for artists compared to non-artists, given their familiarity with the art media. With the sequence of tasks from structured (coloring) to less structured (doodling in a circle) to unstructured (free drawing), it was also hypothesized that the participants would have improved self-perceptions of creativity at the end of the sessions compared with the beginning of the sessions.

Methods

The study used a pre–post quasi experimental design. The participants served as their own controls through the visual self-expression conditions (3 different art-making tasks) and control conditions (4 resting periods with eyes closed). The study was conducted with the approval of the university's institutional review board.

Sample

Participants were recruited through e-mail announcements and flyers posted around the campus. The recruitment announcements indicated that any healthy adult between the ages of 18 and 70 could participate in the study; an e-mail and phone number were included. Those who responded were told (1) the study involved brain imaging and drawing; and (2) no prior artistic experience was required. When potential participants contacted the study coordinator, they were asked whether they identified as artists (visual artists), their gender, and dominant hand use (right or left). Only right-handed participants were included to account for variations due to hand use. The session was then scheduled with the participant. When the participants came to the scheduled session, they completed informed-consent procedures that included understanding the purpose of the study and the steps involved in the use of the fNIRS technology.

Sequencing the study framework included a presession survey, three visual self-expression conditions, four rest conditions, and a postsession survey. The combined sequencing of these steps would take approximately 20 min; during that time the participant would wear the fNIRS band. See Fig. 1a for location of optodes on the PFC and Fig. 1b for the setup of the experimental conditions.

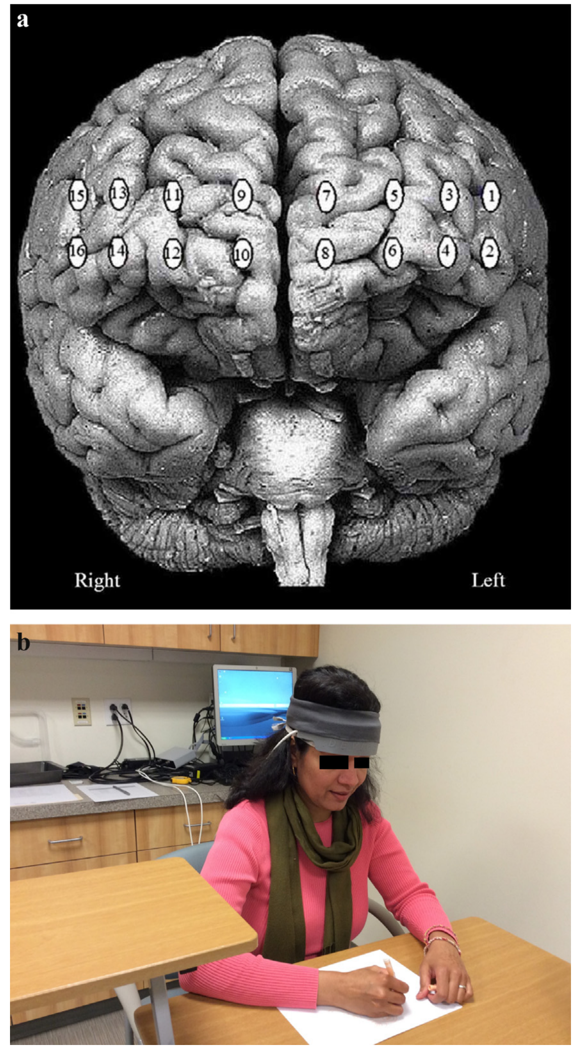

Fig. 1. (a) Location of functional near infrared-spectroscopy optodes on the prefrontal cortex (Ayaz et al., 2012). (b) Setup of the study with the functional near-infrared spectroscopy band.

Participants were told that they would engage in three different visual self-expression conditions: coloring, doodling, and free drawing. They would have 3 min for each of the three drawing conditions preceded and followed by 2 min of rest with their eyes closed. Prior to the start of the session, participants filled out a few questions on self-perceptions of creativity adapted from existing surveys (Beghetto, 2006; Tierney & Farmer, 2002). In addition, the participants were asked about their prior experience on a scale of 'limited,' 'somewhat,' or 'extensive.' At the end of the sessions, participants were again asked to complete the same survey questions on self-perceptions of creativity and to respond to an open-ended question about their experiences with these drawing conditions.

They were also given the opportunity to try out the art materials: three pieces of paper and a set of 12 fine-tipped color markers. Coloring was defined as coloring in the predrawn shape. Doodling was defined as a personalized doodle style that the participant might have used in the past. Free drawing was defined as any drawing the participant chose to create. Participants were offered a predrawn mandala and two pieces of paper with circles on the paper to be used for both the doodling and free-drawing conditions. See Figs. 2–4 for examples of the art materials.

After the participants completed the sequence of the study conditions, they were asked to complete the postsurvey on self-perceptions of creativity and to respond to a question about their

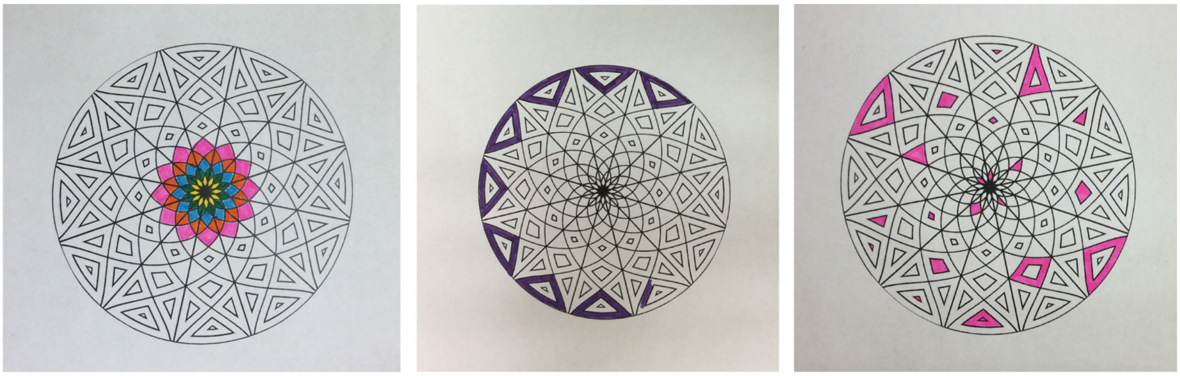

Fig. 2. Examples of coloring done on pre-drawn mandala designs.

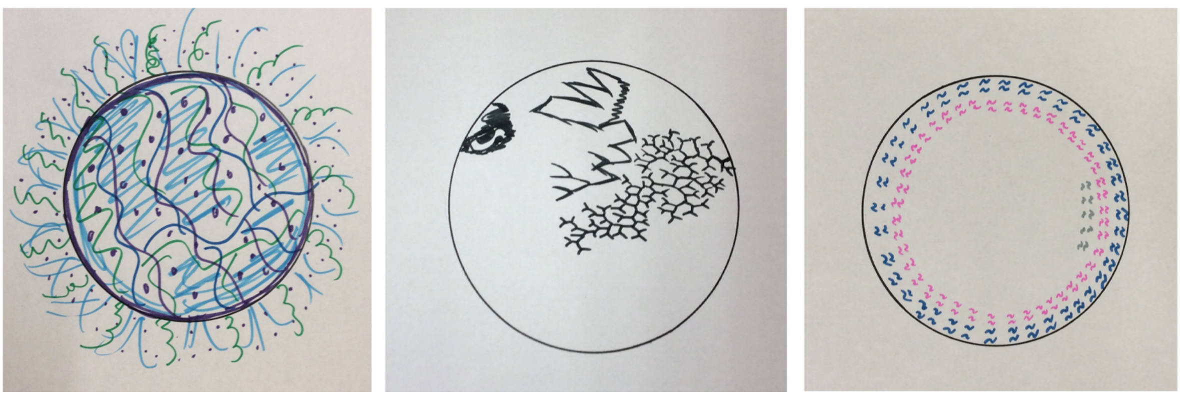

Fig. 3. Examples of doodles using a circle.

experiences with the drawing conditions. They were then given the option of taking the drawings with them. With permission from the participants, photographs were taken to document the coloring, doodling, and free drawing art-making conditions. Participants were given $10 cash in compensation for participating in the study.

fNIRS data

We used a continuous wave fNIR device model 1000. This fNIR system (fNIR Devices LLC, Potomac, MD; www.fnirdevices.com) to obtain images of the cerebral hemodynamics of the PFC. After answering the presession survey, participants were connected to the fNIRS system and their baselines were taken while they visually fixated on a central cross presented on the computer screen. Activation of each participant's prefrontal cortex was monitored throughout the entire time the participants were engaged with the art-making and rest conditions. The sensor had a temporal resolution of 500 ms per scan with 2.5 cm source-detector separation allowing for approximately 1.25 cm penetration depth. The dual-wavelength LEDs were activated in turn, one light source and wavelength at a time, and the four surrounding photodetectors sampled around the active source. The positioning of the light source and detectors on the sensor pad yielded a total of 16 active optodes. COBI Studio software was used for data acquisition and visualization (Ayaz et al., 2011).

For each participant, raw fNIRS data (16 optodes $\times$ 2 wavelengths) were low-pass filtered with a finite impulse response, linear phase filter with order 20 and cut-off frequency of 0.1 Hz to attenuate the high-frequency noise, respiration, and cardiac cycle effects (Ayaz et al., 2011). Each participant's data were checked for any (1) potential saturation (when light intensity at the detector was higher than the analog-to-digital converter limit); and (2) motion artifact contamination by means of a coefficient of variation-based assessment (Ayaz et al., 2010). fNIRS data for each condition block were extracted using time synchronization markers indicating onset and completion of each condition. Hemo-

Fig. 4. Examples of free drawings.

dynamic changes for each of the 16 optodes during each condition block were calculated separately using the modified Beer-Lambert law. The hemodynamic response at each optode was averaged across time for each condition block to provide a mean hemodynamic response at each optode for each block. The final output of each optode was the average oxygenated hemoglobin level for each condition (Ayaz et al., 2012). The differences were first compared between creative visual self-expression and rest conditions and then compared across conditions and across artistic skill using a two-way repeated measures ANOVA, with gender and age included as covariates. The fNIRS data analysis focused on optode 7, which represented activation of the left dorsomedial PFC.

Self-perceptions of creativity

Five questions from Beghetto's (2006) and Tierney and Farmer's (2002) surveys on creative self-efficacy were adapted for use in this study and were used as both a presession and a postsession instrument. This five-item questionnaire asked participants to rate their perceptions of their abilities to (1) have new ideas; (2) have good ideas; (3) have a good imagination; (4) have novel ideas; and (5) solve problems. The survey data were compared using the paired samples *t* tests.

In addition to the questions on self-perceptions of creativity, participants were asked two additional questions. Before the session, they were asked to rate their prior experience with visual self-expression or art making. They were provided with a single question with three choices: limited, some, extensive. After the study session and the completion of the postsurvey, participants were asked to respond to an open-ended question related to their experiences with these art-making activities. The narrative responses about their experiences with the visual self-expression conditions were summarized using thematic analysis (Riessman, 2008), and the recurring themes were tabulated with representative examples.

Results

Study participants

The study sample comprised 26 participants: 11 artists (4 men, 7 women) and 15 non-artists (7 men, 8 women). Participants ranged in age from 20 to 60 years ($M = 32.46$, SD = 11.03). All participants were right-handed and reported being healthy (not unwell or undergoing any medical treatments) at the time of their participation in the study.

Table 1
Mean activation levels and mean change in activation across conditions for optode 7 ($N = 26$).

Condition	Mean	SE	95% CI	Mean change	*p*-value
Baseline	.047	.094	−.149 to .243	–	–
Coloring	.388	.114	.151 to .626	.341*	.023
Rest	.027	.092	−.166 to .219	−.362*	.033
Doodling	.548	.162	.209 to .887	.521*	.021
Rest	−.297	.165	−.640 to .047	−.845*	.005
Free-drawing	.473	.165	.128 to .817	.769*	.011
Rest	.044	.131	−.229 to .316	−.429	.103

CI: confidence interval; SE: standard error.
* $p < .05$.

Findings

fNIRS

We first compared whether there was higher activation of the reward pathway as demonstrated through optode 7 (associated with the left mPFC) during the visual self-expression conditions compared to the rest conditions. A repeated measures ANOVA showed differences in activation across the four rest and three visual self-expression conditions: $F(6,120) = 4.729$, $p < .001$. Results of post hoc comparisons across all intervals are presented in Table 1. As indicated in Table 1, activation levels rose with each of the creative self-expression conditions compared to the rest conditions and returned to baseline levels during the rests. A paired *t* test confirmed that activation on optode 7 was higher during the creative self-expression conditions ($M = 0.46$, SD = 0.68) compared to the rest conditions ($M = -0.03$, SD = 0.30, $t[23] = -2.74$, $p = .012$).

Results of the repeated measures ANOVA allowed us to compare activation on optode 7 across the creative self-expression conditions as well. As shown in Table 1 and Fig. 5, the doodling condition resulted in the most blood oxygenation (activation of PFC) compared with the coloring and free-drawing conditions for optode 7. However, post hoc comparisons indicated that differences in acti-

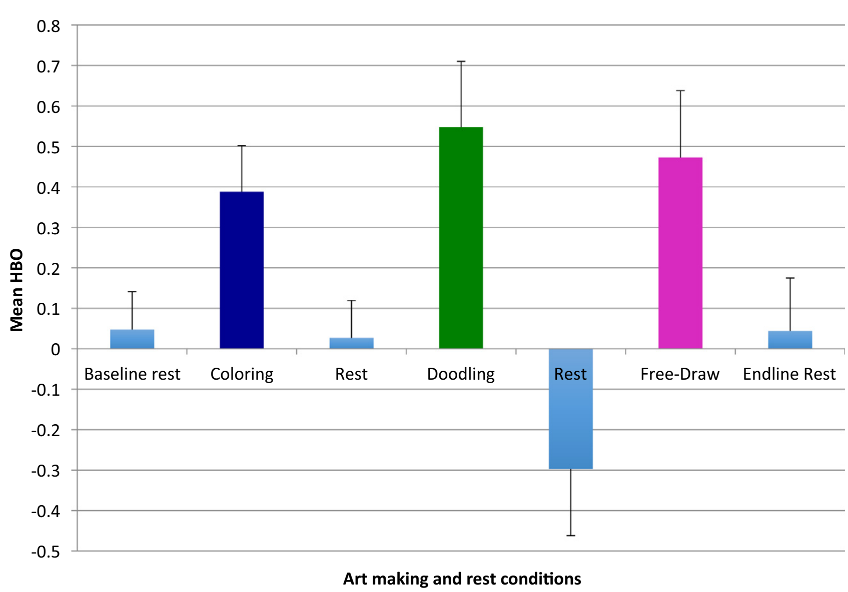

Fig. 5. Mean levels of oxygenation (activation of the medial prefrontal cortex) for each condition.

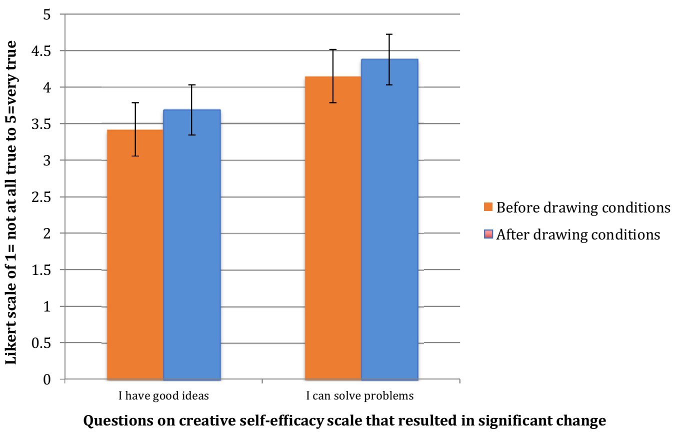

Fig. 6. Changes in self-perceptions of creativity among participants before and after the seven art-making and rest conditions ($p < 0.05$).

vation across the three art-making conditions were not statistically significant ($p = .38–.69$).

The results point toward a possible difference between artists and non-artists related to the reward perception of the coloring condition; however, this difference was not evident in the doodling or free-drawing conditions. In fact, doodling seemed to evoke more brain activation (HbO or oxygenated hemoglobin) in the artists, whereas both artists and non-artists had similar levels of brain activation in the free-drawing condition. The coloring condition resulted in negative brain activation for artists compared with the other two conditions, whereas changes in oxygenation increased brain activation in the coloring condition. For all participants, regardless of skill level, doodling, and free drawing resulted in increased brain activation compared with the coloring condition. The interaction between artist/non-artist and the condition was not significant ($F[6,114] = 1.51$, $p = .18$), perhaps because the study was underpowered to detect the effects of interaction.

Self-perceptions of creativity

This category was assessed using an adapted survey that included five questions asking participants to rate perceptions of their abilities to have new ideas, good ideas, a good imagination, and novel ideas and about their ability to solve problems. Overall, participants' responses to the 5-item survey improved after they completed the three art-making and four rest conditions ($M = .85$, $SD = 1.78$, $t[25] = 4.42$, $p = .02$). Self-perceptions significantly increased following the session conditions specifically for the questions of 'I have good ideas' ($M = -.269$, $SD = .667$, $t[25] = -.059$, $p = .050$) and 'I can solve problems' ($M = -.231$, $SD = .514$, $t[25] = -2.287$, $p = .031$). See Fig. 6.

Experience with session

In their narrative responses about the experience of the art-making conditions, the most common responses referred to enjoyment or relaxation ($n = 16$). Eight individuals mentioned the fact that the experience was fun or enjoyable ('Coloring with markers was fun! Enjoyable & relaxing'), and eight mentioned the relaxing nature of drawing ('Overall it was a very relaxing experience'). In addition, 11 participants described aspects of the experience that they found limiting, such as the time constraints ('The 3-min interval was short, and I was unable to come to a stopping point with my art'), the structure provided ('The circles on the paper for the free drawing were kind of odd in that they were almost in the way'), or the materials that were provided ("markers don't have a lot of control. I usually draw w/pen or colored pencils").

Discussion and implications

The results of this pilot study indicate that all three creative self-expression conditions activated the mPFC and the reward pathway in a way that was significantly different from the rest conditions. The doodling condition evoked the most activation; however, the differences from coloring and free drawing were not statistically significant. There were some indications that there might be differences between artists and non-artists; however, the sample was too small to draw any definitive conclusions. The hypothesis that free drawing would evoke the most activation was not supported. All conditions activated the reward pathway. The hypothesis that self-perceptions of creativity would improve following the sequence of drawing tasks was supported, indicating that even a short series of creative self-expression or art-making tasks completed in approximately 15–20 min can result in individuals perceiving themselves as having good ideas and being able to solve problems. These findings have useful implications in empowering individuals to shift self-perceptions of creative abilities and creative problem solving. These differences were not seen to be related to artistic skills, age, or gender, indicating that all participants, regardless of demographic background, could potentially see such changes. The sample used in this pilot study is small, and any conclusions must be drawn with caution. In addition, Dietrich and Kanso (2010) highlight the challenges of defining and assessing creativity as any one single construct. It is to be noted that we did not ask participants to define creativity or to assess the creative qualities of their artwork in any way; rather we asked them their self-perceptions of having novel ideas, being imaginative, and coming up with good ideas and solutions to problems. These self-perceptions are valuable and warrant further study in terms of what exactly changed for the participants and how they perceived these changes to manifest in their lives.

The instructions for the drawing conditions might also have affected the results. For example, in a previous study, Andrade (2010) found that doodling helped improve memory and retention. The doodling condition in that study was similar to the coloring condition in our study. Participants in Andrade's (2010) study colored in blank squares as part of the doodling condition. In our study, however, we asked participants to engage in doodling with only the frame of a circle provided on an empty page. Moreover, when we invited participants to engage in doodling, it was operationalized for this study as a personalized activity, and almost everyone had a doodling style. Some participants said that they did not doodle much since they used digital devices rather than paper and pencil/pen. Our participants, however, had a style that they identified as their preferred doodling style, which helped them participate in the doodling condition. This preference could be equated to esthetic judgment (Ishizu & Zeki, 2013), leading to increased reward perception and pleasure from creating and viewing the doodle. Rather than serving as a distraction or containing activity that coloring seems to serve, doodling might be a way to engage the reward perception mechanism in an accessible way for artists and non-artists alike. The free-drawing condition, however, did not evoke a distinct response. This finding could have been based on the fact that the free-drawing condition followed the two other conditions in the study sequence and could thus be embedding experiences of the other conditions. In addition, for some participants, free drawing was intimidating, whereas for others, the paper, circle format, and media were restrictive. All of these factors together might explain the indistinct responses to the free-drawing condition.

Bolwerk et al. (2014) highlighted the positive outcomes of art-making versus simply viewing artwork. We have built on this work and have demonstrated the perception of reward generated by art-making through a range of creative self-expression options. We have also provided evidence for a shift in an individual's self-perceptions of his or her creativity in just 15 min of a sequence of art-making tasks. Given that the narratives also corroborated the enjoyable aspects of art-making regardless of gender or age, these are valuable findings for further study. We recognize that the mPFC has multiple roles, including emotion processing, long-term memory processing, and social cognition (Euston et al., 2012; Grossmann, 2013). These roles might also be in play for the drawing tasks, especially the fact that doodling might evoke memories and free drawing might involve making connections between long-term memories and spatiotemporal regions to generate an image. As seen from the narrative responses, drawing itself evokes memories for participants of early school experiences as well as individual differences in whether these memories elicited positive emotions or negative emotions. Further research is needed to better understand the interaction of emotion, reward perception, and visual self-expression.

Because this endeavor is a pilot study, further research is needed to make conclusive clinical recommendations. We can, however, highlight some emergent directions for clinical applications for art therapists. For example, participants reported more improvements in self-perceptions of creativity and problem solving at the end of the three art-making conditions, indicating a simple way to enhance perceptions of creativity in individuals. The potential differences in activation of the reward pathways differed for artists and non-artists, which suggests that it might be valuable for art therapists to consider some sensitivity around the reward pathways. The narrative feedback also indicates differences in participant experiences with the choices of creative self-expression and media. Because no therapists facilitated the art-making conditions, these results further highlight the potential differences based on the opportunity for self-expression and processing the experience. The finding that all drawing conditions activated the mPFC and the related reward pathway in the brain indicates that artistic expression can be a positive experience even if it is practiced for a short time. We did not find any significant differences between artists and non-artists, which also indicates the potential for all participants to enjoy positive experiences from visual self-expression. Art therapists could cite this result as evidence to encourage participants/clients who might be intimidated by drawing tasks and perceive themselves as unskilled in the visual arts. Furthermore, the fact that art can evoke reward pathways indicates that it could potentially be a replacement for other activities that are known to activate these pathways such as addictive behaviors, eating disorders, and mood disorders. Further research is needed to examine the potential of visual self-expression to replace other reward-seeking behaviors like addictions and loss of pleasure conditions like anhedonia (Huhn et al., 2016). In addition, given the evidence that impulse control disorders like attention-deficit/hyperactivity disorder and borderline personality disorder exhibit disturbed functioning in the mPFC, we might explore the role of art-making in addressing these symptoms (Sebastian et al., 2014).

This study has several limitations. It was a pilot study that tested three creative self-expression conditions set up in a sequence from structured to unstructured tasks (coloring in predrawn shapes to doodling to free drawing). It was set up to mimic art therapy practice, which has traditionally helped clients move from structured to more unstructured activities of self-expression. The setup is also, therefore, one of the main limitations of the study, because the creative self-expression conditions were implemented in the same sequence across all participants, and there was only one iteration with each participant. We did not control for the order effect. The participants served as their own controls, and we did not have separate groups for each of the drawing conditions. Moreover, the number of participants is small, and the sample size is further reduced when comparing participant characteristics such as gender, age, and artistic skill levels. It is also possible that any "making" or "doing" task involving the hands might have evoked the mPFC, but we did not test for this. In addition, fNIRS only measures PFC activation, and we did not account for other mechanisms of inner brain structures that might have offered more insight into the experiences of reward perception. In the narrative responses, several participants spoke about not having enough time to complete the tasks. Some participants felt restricted in their creative self-expression by the limited time (3 min) to complete each condition, and others felt constrained by the media choices and the circle shape for the free-drawing condition. The 3-minute time frame was set to accommodate the technology, because the fNIRS band sits snugly on the participant's forehead and might feel uncomfortable beyond 20 min of wear. These short-duration experiences might have affected the reward perception of each drawing condition. Further research might examine how brain activation varies by the creative self-expression condition when participants are given a longer time and different media choices. Newer fNIRS detection technology allows for longer wear, which may also facilitate further study.

Conclusions

This pilot study examined brain activation measured by fNIRS for three creative self-expression conditions—coloring, doodling, and free drawing. The study provided initial findings to indicate that all three art-making conditions activated the mPFC and that this activation was significantly higher than that obtained during the rest condition. Of the three art-making conditions, doodling resulted in maximum mPFC activation compared with the coloring and free-drawing conditions; however, these differences were not statistically significant. Some clinical implications include: the recognition that art-making evokes reward pathways, that even short spans of artistic activity can improve self perceptions of creative abilities, and, art-making could be a way to regulate mood, addictive behaviors and evoke a sense of pleasure. Further study is needed to better understand the specific ways in which art-making is perceived, including expressive activities and aesthetic perceptions of the art product, reward pathways related to art making, art media choices, time on task, identification as an artist/non-artist, and the intersection of emotions and self expression to art making.

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