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Investigation into the Mirror Neuron System's contribution to imitation and autism.

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ABSTRACT

The mirror neuron system (MNS) is a cluster of neurons which activate when an individual performs an action, as well as upon observing another performing an action. This study aimed to expand upon two areas of research into the MNS: autism and imitation. This study consisted of 23 participants that engage firstly, in a visual presentation task then a questionnaire. The findings are as followed:

Imitation

Findings demonstrated that, firstly, which visual field the stimulus was exposed to influenced the participants' reaction time of imitation. Secondly, reaction time was fastest when the right hand was observed and slowest when the left hand was observed, on the right visual field only. This lateralization effect was not significant for the left visual field. Thus, visual presentational effects upon imitation is an interaction, rather than a direct main effect.

Autism

Additionally, there was no relationship between individuals' reaction time and their autistic tendencies.

KEY WORDS:	MIRROR NEURON SYSTEM	IMITATION	AUTISM	AUTISTIC TENDENCIES	VISUAL PRESENTATION

Introduction

The mirror neuron system (MNS) consists of a cluster of neurons that activates when an individual performs an action, as well as when an individual observes another performing an action. Discovered by Rizzolatti et al., (1992) within the F5 area of a monkey's brain as visuo-motor neurons, the monkeys' neurons would activate whilst the monkey picked up a peanut, as well as observing the researcher picking up a peanut also. Whilst there is no study to prove the existence that this system consists of one type of neuron within humans (Rizzolatti, 2005), research does indicate the existence of this system within the motor areas of the human brain (Rozzi, 2015). Therefore, since the discovery, the MNS has been discussed as a mediator for various social cognition, such as the human ability to imitate (Lacoboni, 2012; Keysers et al., 2013; Rizzolatti, 2005; Rizzolatti and Craighero, 2004; Schunke et al., 2015).

Imitational learning has been discussed by Ramanchandran (2000) as a potential explanation for the exponential rise in human evolution. Imitational learning is the ability to observe and copy the actions of others. Ramanchrandran states that whilst various species physically adapt, through generations of successfully passed genetic material and natural selection, humans possess the MNS allowing behavioural adaption to occur instantly. To elaborate, as discussed by Rizzolatti and Craighero (2004), the MNS facilitates the human ability for imitational learning. Thus, the MNS allows humans to observe and copy advantageous behaviours in order to increase the individuals' chance of survival. Therefore, the MNS grants humans with a mechanism that is a faster alternative compared to natural selection.

Modern uses for imitation is embedded within the areas of neuropsychology: motor rehabilitation for stroke recovery (Small, Buccino and Solodkin, 2012) and neurological assessments (Nagahama, Okina and Suzuki, 2015; Moo et al., 2003;

Kipps and Hodges, 2005). Firstly, in relation to motor rehabilitation, Gatti et al.'s (2016) research indicates that the MNS activation increased for finalistic motor tasks, compared to simple and complex motor tasks. This research highlights one important assumption for the relationship between the MNS and imitation; the observation of the action effects the activation of the human MNS and not all observations effect the MNS equally. This assumption should be looked into further as this may affect the efficiency of current neurological assessments, and thus leading into the second neuropsychological area which imitation is embedded within.

Neurological assessments are used to evaluate the effects of brain injury or neurological illness, in particular, assessments of a specific skill is carried out to determine the area of the brain that may have been damaged. Imitational tasks are embedded within neurological assessments, such as the 'interlocking finger test' (Moo et al., 2003) and cognitive assessments for apraxia (Kipps and Hodges, 2005). Imitational tasks are used within neurological assessments as there is a cognitive basis for which (Craighero et al., 2002; Wohlschlager and Bekkering, 2002). This adheres to the neurophysiological nature of the MNS, supporting the notion that imitation consists of a neurological component. This allows a neurophysiological, thus testable, focus for imitational tasks enabling researchers to assess the effectiveness of neurological assessments, which is questioned by Aziz-Zadeh et al. (2006).

Aziz-Zadeh et al.'s research was based upon the investigation of the lateralization of the human MNS, and thus, brain lateralization was prioritized and analyzed. Upon analysis, findings indicated an ipsilateral activation between the lateral visual presentations (participant's visual field), lateralization of the response hand and the area of the human brain. To elaborate, findings demonstrate that there was an increase of brain activation within the right areas, when the stimulus was on the right visual field and the respond hand was the participants' right hand, and vice versa. Hence, Aziz-Zadeh et al.'s research findings demonstrated that there is an ipsilateral connections between the MNS and imitation and that visual presentation effects the MNS. These findings lead to concern for involving lateral visual imitational tasks with the aim to assess brain injury; this may reduce effectiveness, or accuracy, of the assessment. However, this research does not specify how, or whether, an increase activation within the MNS influences the participants' ability to imitate. Visual presentational effects upon imitation therefore, ought to be investigated further to establish beneficial evaluative research towards both neurological assessments and understanding of the human MNS.

With this in mind, this study aims to expand upon Aziz-Zadeh et al.'s research in order to investigate further into visual presentation and the participants' reaction time for imitation. Visual presentation will consist of two independent variables: visual field and the lateralization of the observed hand. Whilst visual field was analyzed within Aziz-Zadeh et al.'s research, lateralization of the hand observed was not analyzed despite participants' being exposed to the right and left hand. Therefore, this study will investigate the effects of both visual field and the lateralization of the hand observed.

Nonetheless, it is important to reiterate that the MNS contributes to other social cognitions, such as action understanding and 'theory of mind, and these may influence individuals' ability for imitation (Schunke et al., 2015; Frenkel-Toledo et al., 2016). Firstly however, a broader perspective of the MNS suggests that this system allows individuals to understand that one's own mental states, intentions and desires can differ to another; or again, 'theory of mind', (Ramachandran, 2000; Oberman and Ramanchandran, 2007). To paraphrase, the MNS allows individuals to view themselves differently to viewing another. Due the nature of the MNS, it is suggested that individuals who are diagnosed with autism have a dysfunctional MNS (Rutter, 1978).

Individuals who are diagnosed with autism express difficulties socially: communication, interaction and imagination (Rutter, 1978). These require the cognitive capability to understand that one's own mental state, desires and intentions can differ to another's, or 'theory of mind'. This lifelong developmental disability, therefore, affects individuals' capability to express 'theory of mind' suggesting that this function is absent, or dysfunctional. This notion that a dysfunctional MNS contributes to autism is supported by a vast wealth of research (Yang and Hofmann, 2015; Vivant and Rogers, 2014; Oberman, et al., 2005; Schunke et al., 2015).

Considering this, as the MNS mediated both theory of mind and imitation, this suggests that if the MNS is dysfunctional, therefore reducing 'theory of mind', then imitation would also reduce in efficiency. Recent research by Schunke et al.'s (2015) supports this by suggesting there is an internal link between autism and imitation. Schunke et al.'s findings demonstrates that individuals who were diagnosed with autism had an increased reaction time for imitation (thus, ability to imitate was slower), compared to those who were not diagnosed. Conclusions expressed that in order to imitate someone there must be an element of another perceived reality, another mind, to which the human MNS is suggested to mediate. If this medium is dysfunctional then the result will adhere to autistic traits, in particular social imagination, and thus reducing the ability to imitate. These findings, therefore, demonstrate support for an internal link between, or the MNS contributing to both imitation and autism.

In light of this finding, autistic tendencies may also effect reaction time for individuals' ability for imitation. Autistic tendencies equate to characteristics of autism within individuals who are not diagnosed, that of which are prevalent within the general population (Rutter, 1978). Whilst research supports the notion that autism is due to a dysfunction (Martineau et al., 2010, Yang and Hofmann, 2015; Vivant and Rogers, 2014; Oberman et al., 2005), the existence of autistic tendencies would suggest that the relationship between autism and the MNS is a degree of function. Thus, a low function would equate to a diagnosis of autism. Moreover, the notion of a degree of function rather than a dysfunction is also discussed and supported within research (Butler, Ward and Ramset, 2015; Schunke et al., 2015; Hamilton, Brindley and Frith, 2007). Thus, if the latter, greater tendencies of autism is derived from a greater human MNS dysfunction, thus predicting slower reaction times for imitation. It is therefore, suggested that there must be pre-existing individual differences within ability for imitation. Ergo, by investigating this individual difference for imitation further evaluative research for neurological assessments can be established. Hence, this study also aims to investigate the relationship between participants' autistic tendency and reaction time for imitation.

In conclusion, it has been highlighted that through investigating the MNS advantages will arise; this study will provide evaluative research into neurological assessments. To delve further, two areas of the human MNS will be explored: imitation and autism.

In order to contribute to imitation, this study firstly aims to develop upon Aziz-Zadeh et al.'s analysis, whether lateral visual presentation affects individuals' ability for imitation. Visual presentation will consist of the area of presentation, right visual field or left visual field, and the lateralization of the observed hand. Hypothesis are as followed:

- There will be a difference for participants' reaction time for imitation when the right hand is exposed, compared to the left hand.

- There will be a difference for participants' reaction time for imitation when the stimulus is exposed on the participants' right visual field, compared to the left visual field.

Secondly, this study aims to investigate further upon Schunke et al.'s research, to expand upon the research into the MNS and autism. This study will investigate the relationship between autistic tendencies, rather than the diagnosis of autism, with reaction time for imitation. Thus, hypothesis are as followed:

- There will be a positive correlation between participants' autistic tendencies and reaction time for imitation.

Method

Design

A within sample, 2 by 2 repeated measures factorial was used within this study to investigate visual presentation and participants' reaction time for imitation. Visual presentation consists of two independent variables. The two independent variables consisted of the right, or left visual field stimuli was exposed too and the lateralization of the observed hand, thus, creating four conditions:

RVF / RH = Right visual field and right hand observed

RVF / LH = Right visual field and left hand observed

LVF / RH = Left visual field and right hand observed

LVF / LH = Left visual field and left hand observed

Secondly, a correlational design was also used within this study to investigate participants' mean reaction time and participants' autistic tendency score.

Participants

23[1] participants were used within this study. All participants were recruited by either volunteer or opportunistic sampling. Whilst opportunistic sampling recruited participants within the MMU campus, the MMU 'Participation pool' enabled some participants to be recruited by volunteer sampling. This is a website that is only available to students undergoing a course at MMU. This study was presented with an invitation (Appendix 1) and the participation information sheet (Appendix 2) allowing students to read. If interested, students selected an available timeslot to participate.

[1] 29 participants were originally in this study. However, six data sets were removed according to participants' handedness score, or their EMG recordings were too noisy.

Through this, students received forty ‘participation points’ after the completion of the study. This added a motivational drive for completing the study, however, this only adhered to the study further; the human MNS activation increases for goal-oriented actions (Koski et al., 2002).

Furthermore, the following restrictions for participating in this study were also presented: no current, or prior, neurological injury or disability. Participants must be able to clearly see a computer screen in front of them, thus have normal, or corrected-to-normal vision. Lastly, participants must be right handed. Gender and age restrictions were not implemented and thus, not recorded. However, it is important to state that all participants were over the age of 18 as all participants were recruited within the university setting.

Regardless of sampling technique, anonymity of participants was ensured. In replace of the participants’ name, a unique identity code was established by the researcher (Appendix 3). Furthermore, the study was approved under the British Psychological Society ethics guidelines (Appendix 4).

Materials

Edinburgh handedness scale (EHS)

The EHS used in this study was an adaption from Oldfield’s (1971) handedness scale: ‘The Edinburgh inventory’ and adapted by Cohen (2008). This adaption consisted of 15-augmented items and was presented as an online self-reported questionnaire[2]. This was to establish the degree of right handedness of the participants. Participants were asked to select which hand, right or left, they use to perform certain tasks, such as: writing, using a computer mouse and holding a cup. In

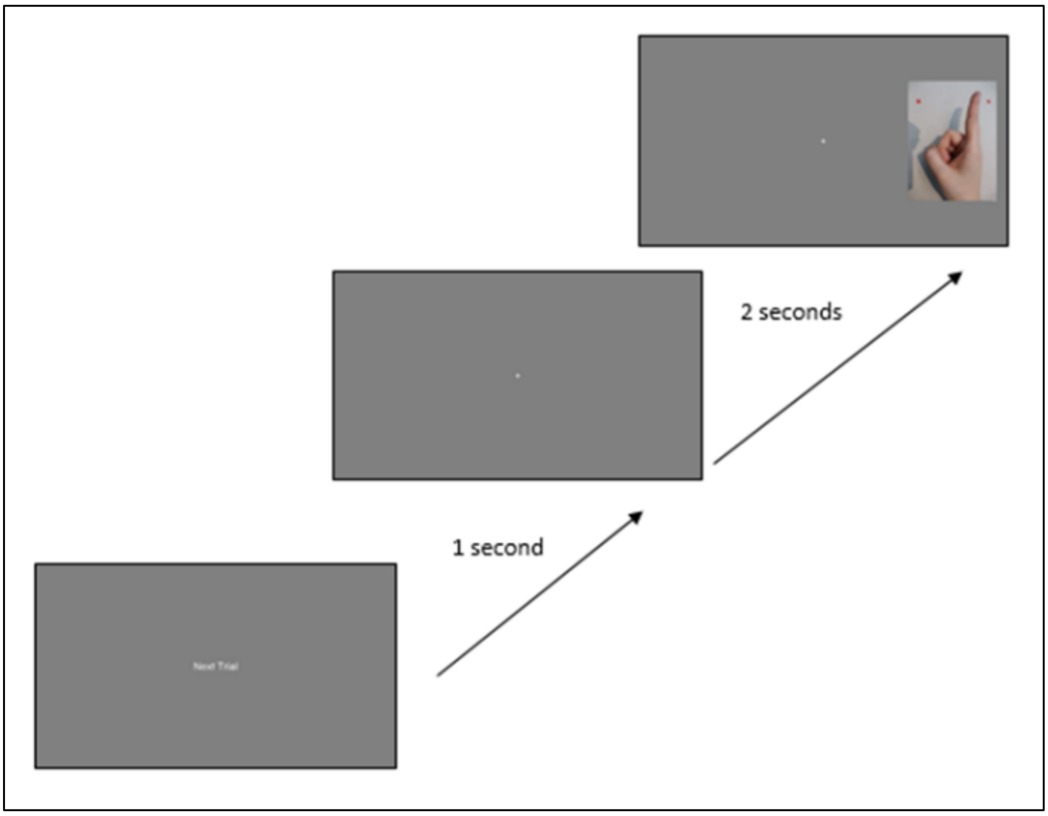
[2] This is assessed though: http://www.brainmapping.org/shared/Edinburgh.php

addition to this, participants had the option to select whether or not they sometimes performed the selected task using their other hand. Upon completion of this questionnaire the results were shown. Handedness of participants ranged from 1st degree (55%) to 10th degree (100%) of right handedness (*M* = 84.2%). Data was removed if participants' handedness degree indicated that they were left-handed or ambidextrous.

PsychoPy

PsychoPy is an application allowing data collection of stimuli presentation for a vast range of research (Peirce, 2009). PsychoPy was used within this study to create a cognitive visual presentation task and this will be elaborated further. Each 4.8 second cycle firstly presented the words "next trial" in the middle of the screen to prepare the participant for the following picture. After 1 second, a small white cross, or fixation point, replaced the words. Prior to the task, the researcher verbally explained to the participant that they need to keep their gaze upon this fixation point. During the presence of the fixation point, a still picture of a completed finger movement either pointing to the right red dot (Appendix 5) or the left dot (Appendix 6) also appeared on either the right visual field or the left visual field. The participants therefore imitated an objective action which does involve activation of the MNS (Mainier et al., 2013). **Figure 1** below demonstrates a visual representation of the cognitive task developed for this study.

Figure 1. A representation of visual presentation task



The pictures presented were 330 millimeters in width and 440 millimeters in height and exposed for 1.80 milliseconds (Moscovitch, 1987). These pictures were randomly presented fifty times, thus, overall two-hundred pictures were exposed to the participant. Fifty pictures were exposed for each condition to reduce potential participant errors from influencing the mean reaction time. The distance between the participant and the screen presenting the visual task was 67 centimeters. Additionally, the visual angle of the exposed pictures were 0.75 degrees on both left and right visual fields.

Two versions of this visual presentation task was used: a ‘trial task’ and the ‘experimental task’. The trial task is a shortened and non-recorded version of the experimental task. The participants were asked to first complete the trial task and were given the option to repeat this as many times as they needed. Once the participant completed the trial task and was ready, the experimental task was initiated. The experimental task lasted approximately 5 minutes and the participants' reaction time was recorded by an Electromyogram (EMG).

<u>Electromyogram (EMG)</u>

An EMG was used to measure the reaction time of participants' imitation, particularly as EMG is a widely used method for measuring reaction time within research (Cabib et al., 2015; Ayala et al., 2014; Nonneke et al., 2014; Kavanagh et al., 2012; Scantlebury et al., 2014). Specifically, EMG's have been used to investigate lateralization as well as hand motor function (Kavanagh et al., 2012). Hence, an EMG was used within this study to ensure accurate reaction time is recorded within participant's finger movements, as implied through the use of this assessment for previous studies. The EMG was administrated through a 'BIOPAC' (MP45). By targeting a specific muscle the EMG recorded contraction and relaxation activity allowing a recorded reaction time, thus EMG measures muscle activity. The specific muscle targeted was the flexor digitorum superficialis muscle which is responsible for the contraction and relaxation of the index finger (Maier et al., 2008; Itoh et al., 2007). This was placed before the trial task to allow the participant to gain comfort and to diminish the temperature difference between electrodes that of which is advised by Maier et al. (2008).

Prior to data analysis, the process of converting the EMG recordings into a reaction time was completed. This conversion consisted of firstly creating a baseline of the participants muscle activity to remove noise and interference. Secondly, the local muscle activity was then established and used as the indicator for the participants' reaction response. The presentation of the stimuli was recorded during the experiment task by a transistor-transistor-logic (USB TTL) module. USB TTL was used to connect PsychoPy to the BIOPAC allowing the researcher to know when, and which, stimuli was exposed and thus, was demonstrated as a 'stimulus delivery'. Lastly, using the established stimulus delivery and response, participants' reaction time was calculated for each stimulus exposure. Through this, a mean reaction time for each condition was established for each participant. Additionally, a restriction was implemented for reaction time, which consisted of the removal of reaction times below 0.05 seconds and above 2.00 seconds. Restrictions were implemented to reduce extreme anomalies.

<u>Adult autism spectrum quotient (AQ) questionnaire</u>

The AQ questionnaire (Appendix 7) was developed to explore non-diagnosed individuals' tendencies for autistic traits. This questionnaire has been used for this purpose within research (Horder et al., 2014; Robertson and Simmons, 2013; Gallitto and Leth-Steensen, 2015; Lau et al., 2013). This questionnaire has fifty items and for each item a corresponding four-point scale ranging from strongly agree to disagree is presented. Participants were asked to indicate, by circling, one answer from the presented scale. This questionnaire was later scored, by the researcher, according to the AQ scoring sheet (Appendix 8) provided with the questionnaire. This questionnaire is openly sourced by the Autism Research Centre (2015).

Procedure

Firstly, participants were asked to read the participant information sheet (Appendix 2) and once the aims and the procedure were fully understood, the participant was then asked to complete the informed consent form (Appendix 9). The unique identity code was then established (Appendix 3) and confirmed by both the researcher and the participant. Furthermore, verbal confirmation was asked of the participant that they do adhere to the requirements for participating in the study. After this, the participant was ask to sit, on a chair, comfortably in front of a computer screen. Before the task, the participant was asked to complete the ‘Edinburgh handedness scale’ and reminded that there was no time restriction for completing this questionnaire. Once completed, the researcher would record the results of the questionnaire, then proceed by placing three electrodes onto the lower right arm of the participant.

Afterwards, the researcher physically demonstrated and verbally explained to the participant the cognitive visual presentational task. Additionally, the task was demonstrated and explained to the participant: by only using their right index finger, imitate the presented finger movement as fast as they could and return to the ‘resting hand position’. The resting hand position consisted of the participants’ fingers relaxed, flexed and not clenched. Explanation of the task, was to ensure that the participant was fully comfortable and also, understood the task required of them.

Only when the participant was ready, the researcher turned off the light and started the trial task. The light was turned off throughout both the trial and experimental task. Completion of the trial task lead to a choice to either complete another trial or continue to the experimental task. If the latter, the researcher would start the recording using an EMG and then start the experimental task. During this time, the researcher would face away from the participant or look at the EMG recording, however not at the participant performing the task. Upon completion, the researcher stopped the recording, turned the light on and removed the three electrodes. The participant was then asked to complete the AQ questionnaire without a time restriction. During this time, the researcher would allow the participant space to complete the questionnaire. Once completed, the participant was given a de-brief (Appendix 10) and the options to ask further questions.

Results

Visual presentation and mean reaction time for finger imitation

Participants' reaction time for imitation was obtained for four conditions. These conditions were derived from two independent variables: visual field the stimuli was exposed too and the lateralization of the hand observed. Thus, the four conditions were as followed: right visual field and right hand observed (RVF/RH), right visual field and left hand observed (RVF/LH), left visual field and right hand observed (LVF/RH) and lastly, left visual field and left hand observed (LVF/LH). **Table 1** below provides the means (*M*) and standard deviations (*SD*) for participants' reaction time of imitation for each condition.

Table 1. Demonstrates the means and standard deviations for each condition

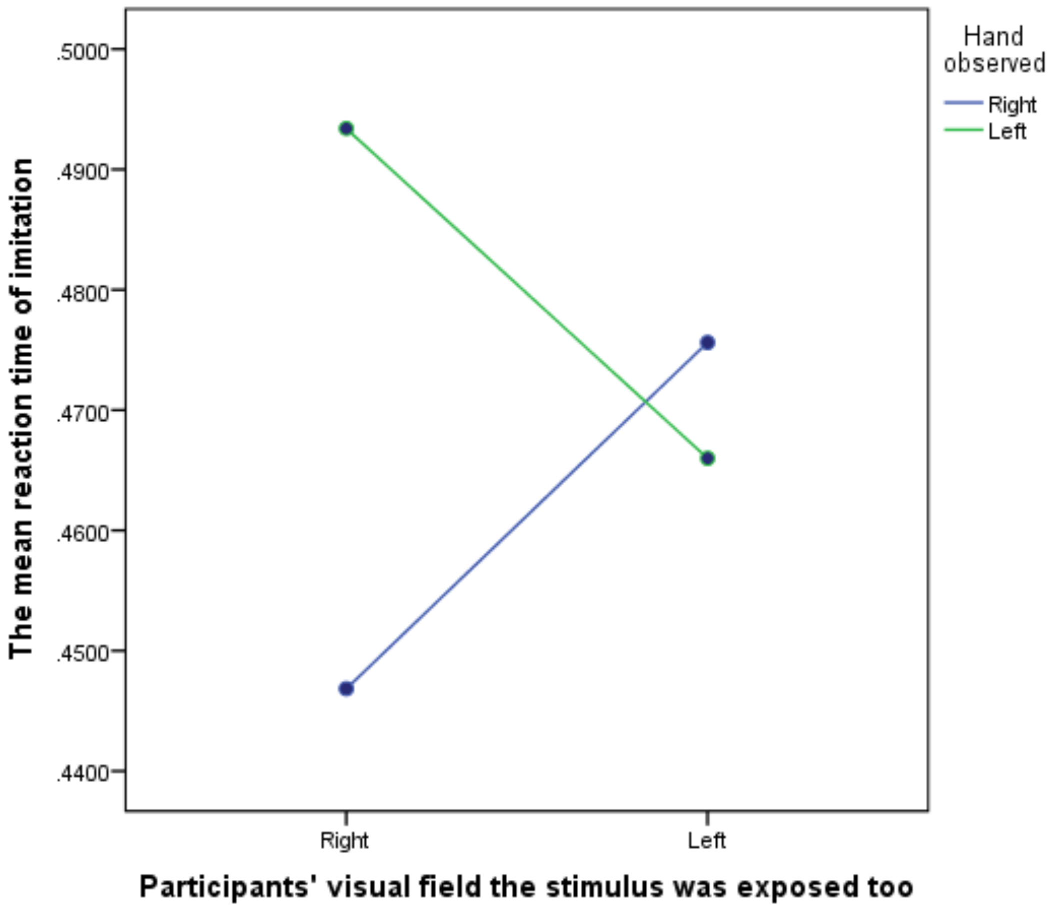
	Visual field					
	Right		Left		Overall	
	M	*SD*	*M*	*SD*	*M*	*SD*
Hand observed						
Right	.45	.09	.48	.08	.47	.05
Left	.49	.13	.47	.11	.48	.04
Overall	.47	.1	.48	.07		

The mean difference between all of the conditions is .04, the highest mean score is RVF/LH (.49), and the lowest mean score is RVF/RH (.45). It is important to reiterate that a low mean score is equivalent to a fast reaction time for imitation, and a high mean score is equivalent to a slow reaction time for imitation. In regards to standard deviation, the difference is .05, the highest standard deviation score is RVF/LH (.13) and the lowest standard deviation score is RVF/RH (.45).

A 2 by 2 within-sample ANOVA was used to establish whether there was an effect between participants' reaction time for imitation and visual presentation. This analysis indicated that the main effect of visual field was not significant: F (1,22) = 0.01, p = .91, partial η^2 = .001. Additionally, that the main effect of the lateralization of the hand observed was also not significant: F (1, 22) = 1.33, p = .26, partial η^2 = .06.

However, there was a significant interaction between visual field and the lateralization of the hand observed: F (1, 22) = 14.33, p = .001, partial η^2 = .39. This interaction is displayed in the figure below (**Figure 2**), demonstrating that imitation was fastest for RVF/RH and slowest for RVF/LH. This effect however, was reduced on the left visual field.

Figure 2. The mean reaction time of participants' imitation and visual presentation



For the right visual field, the mean reaction time was faster when the right hand was exposed (.45) compared to the exposure of the left hand (.49). The mean difference between these conditions were -.05 and the 95% confidence interval for the estimated population mean difference is between -.004 (upper) and -.09 (lower). The effect size was small (d = 0.43). A paired t-test showed that the difference of participants' mean reaction time between these two conditions (RVF/RH and RVF/LH) was significant (t = -2.28, df = 22, p = .033, two-tailed). This support the researcher hypothesis: there will be a difference for participants' reaction time for imitation when the right hand is exposed, compared to the left hand.

However, a paired t-test showed that the difference within participants' mean reaction time between lateralization of the hand observed on the left visual field (LVF/RH and LVF/LH) was not significant (t = 0.67, df = 22, p = .512, two-tailed). Thus, there was no difference between participants' reaction time for imitation and the lateralization of the observed hand when exposed to the participants' left visual field. The mean difference between these conditions were .01 and the 95% confidence interval for the estimated population mean difference is between .04 (upper) and -.02 (lower). The effect size was small (d = .10). This analysis suggests that this may be due to a difference between the two visual fields, thus an additional post-hoc tests will investigate this further.

A paired t-test revealed that the difference within participants' mean reaction time when the right hand was shown between the right visual field, compared to the left visual field (RVF/RH and LVF/RH) was significant (t = -3.04, df = 22, p = .006, two-tailed). Thus, there was a difference between participants' reaction time for imitation when the right hand was observed on the right visual field, compared to the left. The mean difference between the visual fields were -.03 and the 95% confidence interval for the estimated population mean difference is between -.009 (upper) and -.05 (lower). The effect size was small (*d* = .23).

In addition to this, a paired *t*-test revealed that the difference within participants' mean reaction time when the left hand was shown between the right visual field, compared to the left visual field (RVF/LH and LVF/LH) was significant (t = 2.97, df = 22, p = .007, two-tailed). Thus, there was a difference between participants' reaction time for imitation when the left hand was observed on the right visual field, compared to the left. The mean difference between the visual fields were .027 and the 95% confidence interval for the estimated population mean difference is between .05 (upper) and .008 (lower). The effect size was small (*d* = .23). Therefore, the latter two *t*-test both support the research hypothesis: there will be a difference for participants' reaction time for imitation when the stimulus is exposed on the participants' right visual field, compared to the left visual field.

In conclusion, it was found that there is a significant interaction between visual presentation, and no direct main effect were found. A post-hoc analysis consisted of four paired *t*-tests, two between the hand observed (right and left) and two between visual fields (right and left). The two latter post-hoc analysis revealed that there was difference in reaction time due to the difference in visual field. This, therefore, supports one researcher hypothesis: there will be a difference in participants' reaction time for finger imitation when the stimuli is exposed on the right visual field, compared to the left. The first two *t*-tests, which were related to the difference between the hand observed and participants' reaction time, revealed complex results.

It was found that participants' reaction time for imitation was fastest when the right hand was observed and slowest when the left hand was observed, on the right visual field. Yet, there was no difference between participants' reaction time when the right hand was shown, compared to the left hand, on the left visual field. Whilst this does support the researcher hypothesis: there will be a difference in reaction time when the right hand is observed, compared to the left, it is evident that this affect occurred within the right visual field only.

Autistic tendency score and mean reaction time for finger imitation

Derived from the former investigation, participants' overall mean reaction time for finger imitation was calculated (M = .47, SD = .09). Additionally, autistic tendency (AQ) scores were obtained from participants (M = 17.09, SD = 7.56) by the AQ questionnaire. No correlation was observed between participants' AQ score and their mean reaction time. Pearson statistical test for a one-tailed hypothesis revealed this to be not significant (r = -.07, N = 23, p = .37, one-tailed). With this in mind, the researcher hypothesis is rejected (stating there will be a positive correlation) and the null hypothesis is accepted (that there will be no correlation). This suggests that autistic tendencies do not influence participants' reaction time for finger imitation.

Discussion

Visual presentation

It was found that there was a significant interaction between visual presentations, instead of a direct main effect on imitation. To elaborate, reaction time for imitation differed for both observed hands when shown on the right visual field, compared to the left visual field. Reaction time was fastest for the right hand when exposed to the right visual field, compared to the left visual field. Reaction time was fastest for the left hand when exposed to the left visual field, compared to the right visual field. Thus, this study indicates that reaction time for imitation differs when the action is observed on the right visual field, compared to the left. Moreover, this study indicates that the lateralization of the hand observed interacts with visual field, as imitation was fastest when the lateralization of the hand observed corresponded to the visual field. This, therefore, suggests an ipsilateral interaction between both visual presentations. This supports Aziz-Zadeh et al.'s (2006) research as it indicates that the MNS and imitation have an ipsilateral connection.

Additionally, this study also found that reaction time was fastest when the right hand was observed compared to when the left hand was observed, but this effect only occurred within the right visual field. Lateralization of the hand observed does not affect individuals' reaction time for imitation when the hand is observed on the left visual field. This study therefore indicates that reaction time for imitation is different when the right hand is shown compared to the left, however, this only affects the right visual field. This interaction of visual presentation, rather than a direct main effect, was not unexpected. Firstly, it is important to state that participants were only to imitate the action using their right index finger. This study therefore, adheres to Aziz-Zadeh et al.'s (2006) findings as brain activation within the right areas increased when the response hand was the same as the visual field.

Aziz-Zadeh et al. discussed that the relationship between the MNS and imitation is an ipsilateral connection. To rephrase, reaction time should be fastest when the lateralization of the hand observed, visual field and the response hand correspond with each other. This was found within this study as reaction time was fastest when the right hand was shown on the right visual field, and the response hand was also the right hand. However, it is evident from this study that visual presentational effects do not influence the activation of the MNS equally; lateralization of the hand observed only influenced one visual field. Yet, this may expand upon Aziz-Zadeh et al.'s (2006) discussion into the ipsilateral connection between the MNS and imitation.

This present study indicates that lateralization of the hand observed influences imitation under certain conditions: either only on the right visual field, or the visual field corresponding to the participants' respond hand, which is indicated by Aziz-Zadeh et al's (2006) research. Therefore, research ought to investigate this further by repeating this procedure using either left-handed participants, or participants are to respond with their left index finger. According to Aziz-Zadeh et al.'s assumption, reaction time should be fastest when the left hand is observed on the left visual field, as the participants' response hand is also left. Additionally, the assumptions derived from the present study suggests that lateralization of the hand observed will affect one visual field only. Considering Aziz-Zadeh et al.'s findings, the effects of the observed hand should occur on the left visual field, rather than the right as demonstrated in this study. A repeated procedure of this study using left-handed people, or using the left hand as the response hand, will provide greater understanding of the ipsilateral connection between the MNS and imitation found with this study.

In relation to neurological assessments, it is clear from the findings derived from this present study that care should be placed within action imitational tasks, as visual presentation does influence imitation. Assessors for neurological injury should therefore, use standardized pictures to prevent accidentally producing this effect. It is evident that pictures are often used within these tests, such as the interlocking test (Moo et al., 2003), but not all (Kipps and Hodges, 2005). Thus, it may also be suggested that the assessor perform the initiating (observed) action with the same hand if upon the right visual field. It may also be plausible to suggest that the assessor initiate (observed) actions within the individuals' left visual field, as lateralization of the observed hand does not affect the left visual field. Regardless, a standardized requirement for neurological assessments ought to acknowledge these presentational effects: lateral hand effect upon the right visual field, as well as visual field presentation.

However, many neurological assessments involve evaluating the accuracy of imitation, as well as the individuals' rate of response. It is important to highlight that this study does not record, nor measure the accuracy of participants' finger movements. This was acknowledged and procedures were in place to reduce the consequence of participants' errors. Procedures included exposing the participant to 50 pictures from each condition, as well as a trial task ensuring full understanding of the experimental task. However, through utilizing the findings of this study, research ought to prioritize this visual presentation interaction upon individuals' accuracy of imitation. Investigation into the effects of visual presentation and imitation accuracy will also expand upon the current understanding of the MNS, as well as the evaluation for neurological assessments.

Autism

Firstly, this study found that there was no significant correlation between participants' autistic tendency score and their reaction time for imitation. This suggests that whilst imitation is slower for individuals diagnosed with autism (Schunke et al., 2015), it is not apparent in individuals with high autistic tendencies. To elaborate, Schunke et al., found that those who were diagnosed with autism have a slower reaction time for imitation, therefore, suggesting that a dysfunctional MNS influences imitation. Within this study however, it was discussed that autistic tendencies may also influence participants' reaction time for imitation, thus, testing the notion of a degree of function rather than a dysfunction. On the contrary, participants' autistic tendencies did not influence the reaction time for imitation. This, therefore, supports the notion that autism is due to a dysfunction of the MNS (Martineau et al., 2010; Yang and Hofmann, 2015; Vivant and Rogers, 2014; Oberman et al., 2005), rather than a low degree of function as this study theorized. Hence, the MNS does not contribute to autistic tendencies, nor does autistic tendencies affect neurological assessments which involve imitational tasks.

Nonetheless, the task within this study was based upon distal finger imitation, therefore did not have a social component. It is important to reiterate that 'theory of mind' is the cognitive ability to understand another's perceived reality, thus, theory of mind is a social cognition. It may be plausible to suggest that no relationship was found within this present study because of the type of action observed, an objective action rather than a social action. To elaborate, a dysfunctional MNS (autism) does not equate to an inability for imitation, but a slower reaction time for imitation. Individuals may still be able to imitate the action regardless of their autistic tendencies as imitation involves other areas of the brain (Buccino et al., 2004). Research states, however, that communicative and objective imitation are both involved within the MNS (Mainieri et al., 2013). Therefore, it is not plausible to simply suggest that other areas of the brain enables individuals to perform imitational tasks regardless of their autistic tendency.

On the other hand, perhaps the relationship between the human ability to imitate and the MNS is more complex than previously thought. A complex approach may suggest that imitation involves different associative cognitions within the MNS in order to imitate effectively. To rephrase, objective imitation may not involve theory of mind, thus rendering it unaffected by its dysfunction as this study supports. Yet, imitation of communicative action may involve theory of mind and therefore, might be affected if theory of mind is absent or low functioning. Schuke et al. does also discuss the notion that autism may be the result of a localized dysfunction, rather than the dysfunction of the global system. To rephrase, autism may be due to the dysfunction of certain areas, or connectivity, of the MNS and not a dysfunction of the entire system. Whilst this is supported by Hamilton, Brindley and Frith (2007), autistic tendencies were not investigated. Research ought to investigate this further as 'theory of mind' imitational tasks may affect individuals' ability to imitate according to their autistic tendency. In summary, the type of action should be prioritized within future research to investigate the notion that autism is the result of a localized, rather than global, dysfunction of the MNS.

Conclusion

This present study contributes to two areas of research into the human MNS: imitation and autism. Firstly, the present study found no relationship between participants' reaction time and their autistic tendency score. Thus, supporting the notion that autism is due to a dysfunction of the MNS, rather than a degree of function. Secondly, this study contributes to research into the MNS and imitation. The present study found that visual presentation affects individuals' reaction time for imitation, as an interaction rather than a direct effect. More so, this study found that lateralization of the observed hand affects reaction time on the right visual field only. Thus, neurological assessments ought to acknowledge this effect during assessments that involve imitation.

Moreover, potential areas for future research are expressed in order to continue the aims of this study; to expand upon the understanding of the human MNS. Future investigations into the MNS and autism, communicative actions ought to be prioritized. Particularly, the relationship between reaction time for imitation and autistic tendencies ought to be investigated using communicative actions. It was discussed that a relationship may not be present within this study due to the type of action, an objective action compared to a communicative action. For investigating further into the MNS and imitation, two studies were suggested. Firstly, research should investigate whether the response hand of imitation influences the reaction time of imitation under visual presentational effect (both visual field and lateralization of the hand observed). This study will expand and establish the implication that the MNS and imitation consists of an ipsilateral connection. Secondly, research should investigate whether the visual presentational effects found within this study influences individuals' imitational accuracy. This study will expand upon the evaluation of neurological assessments as accuracy of imitation is also assessed along with rate of response. Through these suggested studies the understanding of the human MNS will expand further, as well as contributing to evaluative research into neurological assessments.

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