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The Naturalness of Biological Movement by Individuals with Autism Spectrum Conditions: Taking Neurotypical Individuals' Viewpoint

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Abstract

BACKGROUND: When an action is being observed, it is matched to the observer's internal representation of the action. The more similar, the more the action is perceived as natural. A factor influencing judgement of naturalness is the kinematic features of a movement. However, these features could be altered due to certain conditions that can modify movement such as Autism Spectrum Disorders. As a result, neurotypical observers may fail to interpret the action due to impaired naturalness.

AIM: This work aims to investigate (1) whether neurotypical observers judge the autistic individuals' movement as less natural, (2) which kinematic factors (jerk, acceleration, velocity and size) contribute to their perception and (3) whether cue reliance correlates with autistic traits.

METHODS: Thirty neurotypical participants (20 – 33 years old; 15 males) completed autistic trait screening questionnaires (ADC, TAS-20, AQ). They completed a computer task showing 2D side-to-side arm movements recorded from neurotypical and autistic individuals. Finally, they rated the naturalness of the observed movements, and how certain they were with their answer.

RESULTS: There was a significant difference between the participants' perception of naturalness of the two movement groups. Jerk, acceleration and velocity contributed to shaping the participants' perception with a jerk as the most significant factor. The correlation between the participants' autistic trait and both their perception of naturalness as well as of each kinematic cue were not significant.

CONCLUSION: Our neurotypical participants perceived the autistic movements as less natural. Their perceptions were influenced mainly by the jerk as well as acceleration and velocity of the autistic movements. Autistic traits in the participants did not correlate to their perception of movement naturalness nor to any of the kinematic factors.

Introduction

As a highly social species, humans rely greatly on social interaction. During an interaction, an action produced by the interlocutors needs to be perceived correctly to obtain an appropriate response [1]. To give an appropriate response, a person needs to be able to adjust to the mental state of the person being observed [2]. Our physical movement is a form of non-verbal communication that can demonstrate our mental state [3]. For example, anger is associated with fast and strong movements whilst sadness is with slow and weak movements [3], [4]. However, since the mental state is immeasurable, our perception of an action depends on how similar the observed action with our internal repertoire of actions [5]. Individuals with a movement problem, such as Autism Spectrum Condition, usually find social interaction challenging due to diverging experiencing an action, hence different perception [6], [7], [8].

Our physical action has biological kinematic characteristics obeying the *minimum-jerk (MJ) velocity profile* and the *two-thirds power law*. Contrary to constant velocity profile, the MJ velocity profile describes the smooth speed profile of a biological movement that depicts a bell curve: slow at the beginning, accelerate to the maximum velocity region, and then decelerate toward the end [9]. The two-thirds power law describes a faster movement within the long parts of an ellipse and a slower one within the two curved parts [10].

A prior study [11], wherein participants were required to perform horizontal sinusoidal movements with their right arm, reported that autistic participants had a significantly higher rate of kinematic factors (velocity, acceleration, and jerk) and a wider trajectory than neurotypical participants. Moreover, the level of movement jerkiness in the autistic participants influences their perception of movement naturalness. In other words, the more severe the autistic traits, the more autistic participants will bias the minimum-jerk movements as *less natural* than the constant movements.

However, it remains unclear whether neurotypical individuals perceive movements by neurotypical and autistic individuals differently, and whether the size of the trajectory plays a role in the neurotypicals' perception. Therefore, this experiment aims at investigating *(1) whether neurotypical individuals perceive movements by autistic individuals as less natural, (2) which movement factors contribute to naturalness perception,* and *(3) whether cue reliance correlates with autistic traits*.

Material and Methods

Participants

Thirty neurotypical participants (15 males) between 20 – 30 years old (*M*: 25.10 years, *SD*: 3.29 years) were recruited. One participant was left-handed. All participants submitted informed consent before their participation.

Prior to doing the experiment task, participants completed three screening questionnaires: the *Adult Developmental Coordination Checklist (ADC)* to identify Developmental Coordination Disorder (cut-off score: 65), *Autism Spectrum Quotient (AQ)* to measure the presence of autistic traits (cut-off score: 32), and *Toronto Alexithymia Scale 20 (TAS-20)* to measure the presence of alexithymic traits (cut-off score: 60). To facilitate statistical analysis, data containing technical difficulties and a data of left-handed participant were excluded. The remaining number of participants was 28 (15 males; M: 25.14 years, SD: 3.35 years) who were all right-handed.

Experiment Design

Each participant accomplished four blocks of visual stimuli. Each block comprised of 12 neurotypical and 12 autistic arm movements in a randomised order. Participants were not informed of the type of movement. Participants could take a break between each block as long as they needed. After watching every target movement, participants were asked about to what extent *(1) they perceived the movement as natural* and *(2) they were certain of their perception*. Participants gave a rate by putting a mark within a line of blind scale starting from 0 (not natural/certain) to 100 (very natural/ certain) per cent.

The twenty-four target movements were derived from a previous study in which neurotypical and autistic participants performed horizontal sinusoidal motions with their right arm [11]. The original movements were in 3D form. For this experiment, these movements were simplified into 2D (*x*-plane only) version with *MATLAB and Statistics Toolbox R2008b* (The MathWorks, Inc., Natick, Massachusetts, USA) and were trimmed into five-second clips containing each kinematic factor (jerk, acceleration, and velocity) and size (collectively mentioned as *movement factors* in this article).

All statistical data were analysed with the *SPSS version 24* (IBM Corp, Armonk, New York, USA). *Paired-samples t-test* was used to compare the naturalness perception and certainty. Individual correlations for each participant were run between naturalness perception and each movement factor (collapsed across neurotypical and autistic targets). Following this, *one-sample t-tests* were performed to examine if each factor gave a significant influence on naturalness perception. *Pearson correlation tests* were used to determine the correlation between *participants' autistic traits* and *(1) their perception of naturalness*, and *(2) the perception of each movement factors*.

Results

Figure 1A represents a significant difference found in the perception of naturalness between neurotypical (M = 56.39%, SD = 9.48%) and autistic (M = 50.32%, SD = 9.35%) movements; $t(28) = -3.16$, $p = 0.004$.

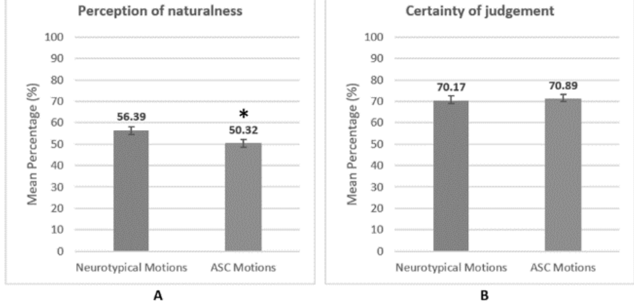

Figure 1: Group-level analysis revealed that the neurotypical participants (A) perceive autistic movements as less natural than the neurotypical ones, and (B) are certain with their judgements on both type of movements

Figure 1B shows no significant difference in the certainty when observing neurotypical (*M* = 70.17%, *SD* = 12.62%) and autistic (*M* = 70.89%, *SD* = 12.85%) movements; *t* (28) = 0.87, *p* = 0.388.

Table 1: Mean value of the movement factors against the correlation coefficient value of zero

Movement Factor	*M*	*SD*
Jerk	-0.257	0.145
Acceleration	-0.225	0.188
Velocity	-0.087	0.191
Size	-0.060	0.278

Table 1 represents the mean value of each movement factor against a correlation coefficient value of zero. The mean of jerk (*M* = -0.26, *SD* = 0.14) was significantly different from zero, 95% CI [-0.31 to -0.20], *t* (28) = -9.55, *p* < 0.001. The mean of acceleration (*M* = -0.22, *SD* = 0.19) was significantly different from zero, 95% CI [-0.30 to -0.15], *t*(28) = -6.44, *p* < 0.001. The mean of velocity (*M* = -0.09, *SD* = 0.19) was significantly different from zero, 95% CI [-0.16 to -0.01], *t* (28) = -2.46, *p* = 0.020. However, the mean of size (*M* = -0.06, *SD* = 0.28) was not significantly different from zero, 95% CI [-0.16 to 0.05], *t* (28) = -1.14, *p* = 0.262.

Table 2: Correlation between the perception of target movements and autistic traits

Type of Movement		ADC	TAS	AQ
Neurotypical	*R*	0.325	-0.060	-0.032
	p	0.086	0.756	0.871
Autistic	*R*	0.146	0.108	0.074
	p	0.448	0.576	0.703

Note: *r:* Pearson correlation coefficient; *p:* significance (2-tailed; correlation is significance at *p* < 0.05 (*) or *p* < 0.01 (**)).

Table 2 shows no statistical significance was found between mean scores of screening questionnaires and naturalness perception of neurotypical and autistic movements.

Table 3: Correlation between movement factors and autistic traits

Type of Factor		ADC	TAS	AQ
Jerk	*r*	0.127	0.180	0.291
	p	0.511	0.349	0.126
Acceleration	*r*	-0.113	0.193	0.233
	p	0.559	0.315	0.225
Velocity	*r*	0.260	-0.030	-0.053
	p	0.173	0.878	0.786
Size	*r*	-0.211	0.125	0.064
	p	0.272	0.519	0.742

Note: *r:* Pearson correlation coefficient; *p:* significance (2-tailed; correlation is significance at *p* < 0.05 (*) or *p* < 0.01 (**)).

Table 3 reveals no statistical significance between the mean scores of the screening questionnaires and the perception of each movement factors.

Discussion

Our results showed that *the autistic movements were perceived as less natural than the neurotypical ones*. Also, they anecdotally reported that they were aware of some arm movements that had irregular smoothness because of higher jerkiness. In other words, neurotypical individuals characterised the autistic arm movements as less natural because the abnormal kinematic feature did not fit their internal representation [5], [11], [12].

In terms of movement factors, *jerk gave the most impact on the perception of naturalness, followed by acceleration and velocity*. Our results agree with prior reports that have stated increased kinematic profile in individuals with autism [5], [11]. On the other hand, *the size of the trajectory did not affect perception*. This may be attributed to the human visual instinct that focuses on kinematic cues [13]. Therefore, it is likely that the atypical kinematic features in the autistic movements are caused by aberrant mechanism underlying the individuals' motor actions.

The sensorimotor information that comes throughout a kinematic experience is integrated by the motor control system lying within the cerebellum. This system consists of *feed-forward control* in the anterior cerebellar lobe, which plans a desired motor action based on internal representation, and *feedback control* in the posterior cerebellar lobe, which is responsible for corrective adjustment to reduce imprecision of an ongoing motor action [14]. In the autism group, an increase of jerk in their movement may be linked to a dominating feedback control [14], [15]. It may be a result of deficiency of Purkinje cells – a group of cells that function as the primary integration neurons and the sole output of all cerebellar motor coordination particularly in the posterior lobe [16] as well as inhibitory neurons that release gamma-aminobutyric acid [17]. These functions are deprived in the autistic individuals due to reduced cell size [18] and overactivity of the neuroinflammatory process [19].

Finally, *no correlation was found between autistic traits and neither the participants' naturalness perception nor each movement factors*. This finding is inconsistent with the previous study [11] where the movement data were derived from. This may be due to the different nature of the participants involved. The current study recruited solely neurotypical participants which may also be the limitation of this study.

The social impairments in the autism group may not only a result of an aberrant motor control system but also of a misinterpretation by neurotypical observers [5], [20]. Autistic students were reported as having clumsy movement in their childhood [21] and showing minimal social interaction in their adolescence which makes them prone to bullying by their neurotypical peers [22]. Unfortunately, these students would develop a negative sensitivity over time that makes them interpret the non-bullying situation as bullying [23]. This case depicts how abnormal movement in autistic individuals would result in negative feedback from the observers, and how the negative feedback would reshape their internal representation of mental states toward negativity. Therefore, there is a demand to understand the mechanism underlying aberrant autistic behaviour from a neurotypical point of view is important, particularly in a clinical or educational setting where an observation is carried out by *neurotypical assessors* who have the authority to design intervention programmes for autistic individuals.

In conclusion, neurotypical individuals perceived the movements made by individuals with Autism Spectrum Conditions as less natural. The perception was influenced by all kinematic factors, particularly jerk, but not by the size of the movement. The autistic traits presented in neurotypical individuals did not correlate with their perception of movement naturalness nor each movement factors. Given the significant influence of kinematics in social interaction, research in this area may give further insight into the development of an intervention programme for autistic people. Future exploration may benefit from replicating this experiment in the autism group to clarify whether they would have a different perception of naturalness of movements in 2D form.

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