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Brief article

Perceiving affect from arm movement

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Abstract

We examined the visual perception of affect from point-light displays of arm movements. Two actors were instructed to perform drinking and knocking movements with ten different affects while the three-dimensional positions of their arms were recorded. Point-light animations of these natural movements and phase-scrambled, upside-down versions of the same knocking movements were shown to participants who were asked to categorize the affect of the display. In both cases the resulting confusion matrices were analyzed using multidimensional scaling. For the natural movements the resulting two-dimensional psychological space was similar to a circumplex with the first dimension appearing as activation and the second dimension as pleasantness. For the scrambled displays the first dimension was similar in structure to that obtained for the natural movements but the second dimension was not. With both natural and scrambled movements Dimension 1 of the psychological space was highly correlated to the kinematics of the movement. These results suggest that the corresponding activation of perceived affect is a formless cue that relates directly to the movement kinematics while the pleasantness of the movement appears to be carried in the phase relations between the different limb segments. © 2001 Elsevier Science B.V. All rights reserved.

Keywords: Biological motion; Affect; Categorization; Kinematics; Multidimensional scaling

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1. Introduction

Our day to day movements serve the primary function of achieving the variety of tasks which sustain our existence. While these movements are not necessarily communicative, common experience would serve to tell us that they often do carry a message. One way to investigate such movement in isolation of other visual cues is to present it as point-lights that show only the motion of the joints (Johansson, 1973). Although these displays are impoverished they are spontaneously organized into the percept of human movement and basic levels of competence have been demonstrated for the recognition of properties of the actor and action (Barclay, Cutting, & Kozlowski, 1978; Cutting & Kozlowski, 1977; Hill & Pollick, 2000; Kozlowski & Cutting, 1977; Mather & Murdoch, 1994; Runeson & Frykholm, 1981, 1983). In this research we examine a particular aspect of the interpretation of human movement – how affect is perceived from the arm movements of knocking and drinking actions.

The problem of recognizing emotion from human movement has been explored for the special case of the interpretation of stylized dance movements (Dittrich, Troscianko, Lea, & Morgan, 1996; Walk & Homan, 1984). Of the six emotions examined (surprise, fear, anger, disgust, grief/sadness, joy/happiness) it was found in both studies that anger was the most reliably identified emotion. Other differences among the identifiability of the different emotions were noted though they fell into no particular pattern between the two studies. The overall rate of recognition for the six emotions reported by Dittrich et al. (1996) was 63% for point-light displays and 88% for full-video displays. These studies provide good evidence that stylized movements can be seen as expressive, but do not address the more general case of movements which are not stylized.

With affect it is possible to discuss not only the accuracy with which an affect is recognized, but also to examine the apparent structure of the representation of affect. A number of descriptive models for the structure of experienced affect have been suggested (Larsen & Diener, 1992; Russell, 1980; Thayer, 1989; Watson & Tellegen, 1985). The essential properties of the various models describe a structure that is anchored by two bipolar but independent dimensions of experience (pleasantness and activation) with the different possible affects located on a circle centered at the origin (Yik, Russell, & Barrett, 1999). This circular formation has led to such models being termed 'circumplex' models of affect. Both dimensions of a circumplex model correspond to the conscious experience of affect rather than pleasantness corresponding to the affect itself and activation being modulated by simple physiological arousal.

One important issue to consider is that the circumplex model has been established as a model of one's own experiences of affect and thus would not necessarily apply to the perception of affect. However, there is evidence to support the prediction that an internal model of one's own experience could serve in the perception of the movement of others. For example, a number of investigations into the perception and production of arm movements indicate that visual and motor processing interact whilst an observer watches an action (Decety & Grezes, 1999; Rizzolatti, Fadiga, Fogassi, & Gallese, in press; Rizzolatti, Fadiga, Gallese, & Fogassi, 1996; Vogt, in press-a,b). Moreover, evidence from the study of biological motion (Shiffrar & Freyd, 1990, 1993; Thornton, Pinto, & Shiffrar, 1998) indicates that the perception of biological motion relies on more than just low-level motion detectors specialized for human movement (Mather, Radford, & West, 1992; Neri, Morrone, & Burr, 1998). Thus, it appears reasonable to conjecture that an internal model of affect would be part of the processes involved in organizing the perception and categorization of affect.

2. Experiments 1 and 2

Two experiments were performed to investigate how affect is perceived from point-light displays of human movement. In Experiment 1 we presented knocking and drinking movements with ten different affects and measured the ability of participants to categorize affect. In Experiment 2 we performed the same categorization task with the same knocking movements, however the relationship among individual points was distorted by displaying the motions upside-down and with scrambled phase (Bertenthal & Pinto, 1994). For both experiments we examined the perception of affect within the framework of a psychological space and related aspects of this psychological space to physical properties of the movements. (Examples of the displays used are available on the World Wide Web at http://www.psy.-gla.ac.uk/~frank/demos.html)

2.1. Methods

2.1.1. Movement collection

The movement data were obtained using a three-dimensional position measurement system (Optotrak, Northern Digital). Positions of the head, right shoulder, elbow, wrist, and the first and fourth metacarpal joints were recorded while the actor performed a movement.

To obtain the knocking and drinking movements with affect, two actors were instructed to read a brief story that set the scene for the movement to be performed with a particular affect. Measurements of the ten affects (afraid, angry, excited, happy, neutral, relaxed, sad, strong, tired and weak) were obtained for both actors who performed three repetitions each for both drinking and knocking actions. This yielded a total of 120 movements (ten affects × two actors × two actions × three repetitions). However, due to recording difficulties data were lost for two movements of one actor.

Each movement record was processed to obtain the start and end of the movement as well as other kinematic properties such as tangential velocity, acceleration and jerk of the wrist. The start of the movement was defined as the point 116 ms before the tangential velocity of the wrist rose above a criterion value, and the end by the point 116 ms after the velocity passed below the criterion. This start/end velocity criterion was defined as 5% of the peak tangential velocity of the wrist.

2.1.2. Stimuli

In both experiments each point of the recorded arm movement was presented as a point-light on a graphics computer (Octane, SGI) from a sagittal view. However, in Experiment 2 the displays were altered by showing them upside-down and randomly phase shifting the points. To phase shift the points, they were re-sampled so that each point from the sequence started at a randomly different stage during the movement cycle from the other five points. This manipulation of the displays changed the global relationship among points but not the motion of individual points.

2.1.3. Design

In both experiments displays were blocked by the possible combinations of actor and affect, and for each block participants viewed all repetitions of each of the ten affects. Experiment 1 consisted of four blocks and Experiment 2 consisted of two blocks.

2.1.4. Participants

Two separate groups of 14 Glasgow University student volunteers were recruited as participants for Experiment 1 and Experiment 2; all were naive to the purpose of the study and were paid for their participation.

2.1.5. Procedure

Experiment 1 took place over two sessions, each containing two blocks. Participants were instructed that they would see a point-light display of a human arm movement and be asked to categorize it. In the first session participants were given a practice session of four trials (one from each block of trials) to familiarize them with the equipment and procedure; this was followed by the first two blocks of trials. The order of blocks was randomized.

Experiment 2 contained only two blocks of trials made up of knocking movements. Participants were not informed that the point-light stimuli represented a human motion.

In both experiments, for each trial, participants viewed a computer display of a movement and were then presented with a dialog box that contained the names of the ten possible affects. They chose a single affect by clicking the mouse on the matching affect.

2.2. Results and discussion

2.2.1. Experiment 1

Over all the trials participants answered correctly 30% of the time; ranging from 15% (strong) to 50% (afraid) correct, this was significantly better than the chance value of 10% ($t(13) = 20.3$, $P < 0.005$, two-tailed). Although the overall recognition rate was not high this could be partially accounted for by some consistent misidentifications. For example, weak movements were identified as weak, sad or tired with equal frequency. Other possible explanations for the low recognition rate are that the arm movements themselves do not effectively communicate affect or that presentation of the movements as point-lights impairs recognition.

To evaluate the possible explanations for the low recognition rate a control study was done comparing recognition of afraid, angry, happy, neutral and sad knocking movements for presentation by both full-video and point-light displays.[1] Results of this study indicated an average recognition rate of 59% for point-lights and 71% for full-video, both of which were revealed by *t*-test to be significantly different from the chance value of 20% ($P < 0.005$). Additionally, a 2 (display) × 5 (affect) ANOVA was performed and revealed a significant effect of display ($F(1,7) = 20.39$, $P < 0.005$). These results are reminiscent of the results of Dittrich et al. (1996) for full-body, stylized dance movements which showed recognition rates of 63 and 88% correct for point-light and full-video displays, respectively. It would thus appear that simple arm movements, while not as effective as stylized dance movements, are by themselves effective in communicating affect and that both confusions among similar affects and point-light presentation contributed to the low recognition rates.

To better understand the structure of the results from Experiment 1, a psychological space of the affects was constructed using a multidimensional scaling procedure (Kruskal & Wish, 1978). The particular multidimensional scaling algorithm used was a non-metric, individual scaling (INDSCAL) algorithm. To obtain the input for this algorithm the 10×10 confusion matrix of response rates for each of the four block conditions was first converted to distances by subtracting the response rate from 1.0, and then these distances were averaged across the diagonal. In this way items which were confused with one another had smaller distances from one another than those which were not. The resultant solution was a unique two-dimensional psychological space (see Fig. 1a) with $r^2 = 0.87$ and stress $= 0.15$. The first dimension accounted for most of the variance, approximately 70%, and the second dimension for 17% of the variance. For the psychological space to conform to a circumplex model we would expect that the affects be arranged approximately in a circle around the origin and that one dimension should span affects from unactivated to activated while the other dimension spans affects from unpleasant to pleasant. Visual inspection of Fig. 1 indicates that the psychological space of affects conforms to a circumplex structure with the ten movements scattered on a circle around the origin with the first dimension appearing to span activation and the second dimension appearing to span pleasantness.

[1] The stimuli used for the control experiment included point-light and full-video displays of afraid, angry, happy, neutral and sad knocking movements. The point-light displays were obtained from the original data set used in Experiments 1 and 2. Since video clips of these original data did not exist two additional actors were filmed doing affective arm movements and the clips were edited so that the face region was obscured by an oval. In the experiment, displays were blocked according to condition (point-light and full-video) and actor, so that a participant always saw the movements of both actors for one condition before they saw the other condition. For each actor, there were 15 stimuli (five emotions × three repetitions of each movement) which were repeated three times yielding 45 movements in each block of displays.

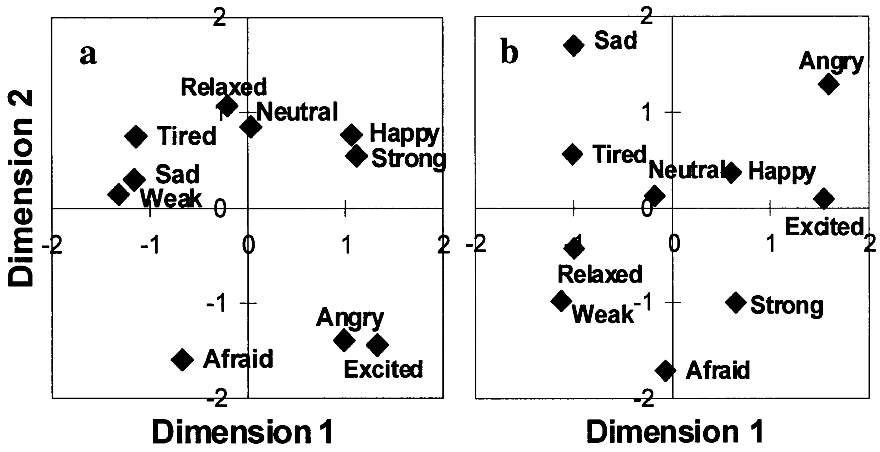

Fig. 1. (a) The psychological space obtained for Experiment 1. (b) The psychological space obtained for Experiment 2.

2.2.2. Experiment 2

For the upside-down phase-scrambled displays, none of the participants reported that the stimuli looked like a knocking arm movement. However, approximately half of them reported seeing some form of human movement from the displays. Over all the trials participants answered correctly about 14% of the time and the range of performance was 4% (afraid) to 34% (excited); this was significantly better than chance ($t(13) = 4.1$, $P < 0.005$, two-tailed). The psychological space (Fig. 1b) was constructed as described above using a matrix from each of the two block conditions. The resultant two-dimensional solution provided by the INDSCAL algorithm had $r^2 = 0.77$ and stress = 0.19. The first dimension accounted for 49.5% of the variance and the second dimension accounted for 27.3% of the variance.

Comparison of the psychological space between Experiments 1 and 2 indicates a similar structure for Dimension 1 and a different structure for Dimension 2. This was indicated by a correlation coefficient of 0.90 between the Dimension 1 values and a correlation coefficient of 0.10 for Dimension 2 values. In Experiment 1 Dimension 2 conformed to the pleasantness axis of the circumplex model while no such structure was apparent in Experiment 2.

2.2.3. Comparison of psychological space to movement kinematics

We examined the movement kinematics to see whether any physical properties of the movement were related to either of the two dimensions defining the psychological space. To do this we first took the instantaneous measures of the wrist kinematics (velocity, acceleration and jerk) and obtained the kinematic markers of duration, average velocity, peak velocity, peak acceleration, peak deceleration and jerk index (jerk index was defined as the magnitude of the jerk averaged over the entire movement and relates to the smoothness of a movement; Flash & Hogan, 1985). These kinematic markers were next correlated to the Dimension 1 and

Table 1
Correlation of movement kinematics of the wrist to the coordinates of the psychological space (Pearson's r)

Kinematic property	Experiment 1		Experiment 2	
	Dimension 1	Dimension 2	Dimension 1	Dimension 2
Duration	−0.85	0.65	−0.96	−0.16
Average velocity	0.92	−0.49	0.95	0.24
Peak velocity	0.91	−0.53	0.94	0.11
Peak acceleration	0.83	−0.68	0.96	0.17
Peak deceleration	−0.79	0.57	−0.91	−0.29
Jerk index	0.83	−0.59	0.94	0.25

Dimension 2 coordinates of the ten affects in the psychological space. Results of all these correlations are presented in Table 1, and Fig. 2 shows an example of this relationship.

From Table 1 we can see that for both Experiments 1 and 2 the Dimension 1 (activation) coordinate of an affect correlated with the kinematic markers in such a way that energetic motions were positively correlated with shorter duration and greater magnitudes of average velocity, peak velocity, acceleration, deceleration and jerk. For Dimension 2 in Experiment 1 we found that to a lesser extent there was a tendency of longer duration and smaller magnitude of the other kinematic markers to be correlated with positive affect. We examined this further by rotating the psychological space to find the orientation which maximized the r^2 values of the correlation with the six kinematic markers (Shepard, 1972). It was found that for Experiment 1 a 27° counterclockwise rotation, and for Experiment 2 a 12° clockwise rotation resulted in the highest correlation with the kinematic markers. These rotations resulted in average r^2 values of 0.88 for Dimension 1 and 0.03 for Dimension 2 in Experiment 1 and 0.86 for Dimension 1 and 0.01 for Dimension 2 in Experiment 2. From these results it can be seen that while the original psychological space is roughly oriented so that energy in Dimension 1 is correlated with the speed of the movement, rotation of the space can improve the correlation.

3. Discussion

The results of Experiment 1 showed that the psychological space resulting from the perceived affect of arm movements conformed to a circumplex structure with one dimension corresponding to an activation axis and the other axis corresponding to a pleasantness axis. Moreover, the activation axis of the circumplex was correlated to physical characteristics of the movement in a consistent manner such that greater activation was related to greater magnitudes of velocity, acceleration and jerk of the movement. This relationship between the activation axis and movement kinematics was preserved even if, as in Experiment 2, the displays were substantially altered so that they no longer were consistent with an arm movement.

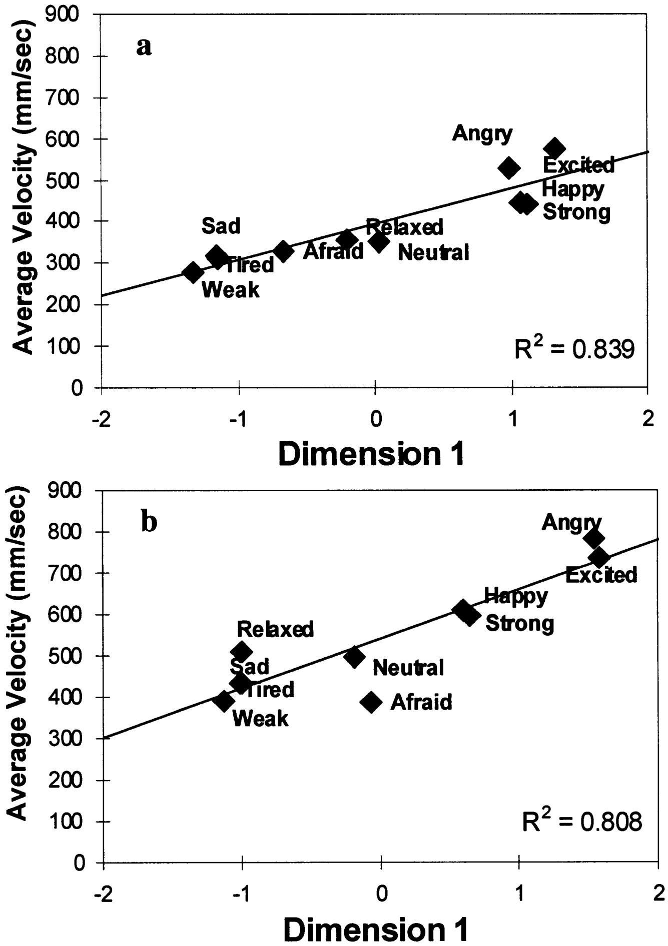

Fig. 2. Plots of the average velocity of an affective movement versus the Dimension 1 coordinate obtained in the psychological space. The results are shown for (a) Experiment 1 and (b) Experiment 2. Similar results are obtained for plots of the other kinematic markers versus Dimension 1.

The results generally indicated that activation was more robustly recovered than pleasantness. One possible reason for this is that by its nature movement is a more natural indicator of physiological arousal and its associated neural mechanisms. Another possibility, as discussed by Bassili (1979) in regard to discrimination of emotion from point-light faces, is the redundancy of motion information. We found that all the various kinematic measures of the wrist were correlated to the activation axis. Moreover, given that the arm is a linked kinematic chain we could expect further correlation with other joints such as the elbow. Thus, the robustness of the activation axis could be explained by the redundancy of kinematic information available to judge activation. Consistent with this and the independence of activation and pleasantness we can conjecture that the information for judging pleasantness would be available from a cue with less redundancy and independent of kinematics.

The finding of a circumplex structure for perceived affect is consistent both with duality between the perception and production of movement as well as a role for high-level information in the interpretation of motion derived from human movement. In addition, the continuous structure of the circumplex model parallels the smoothly varying range of speeds with which a movement can be performed. Thus, it would appear that the mapping between stimulus properties and representation of affect is a fairly direct one for the activation axis. However, such a direct connection between stimulus and representation has proven elusive for the second dimension of pleasantness. Other research has suggested that subtle phase relations between the joints (Amaya, Bruderlin, & Calvert, 1996) might possibly carry information about affect. Comparison of the results between Experiments 1 and 2 supports this view. However, the present data do not indicate which aspect of the phase relations is the crucial one.

The result that the activation dimension could be accounted for by movement kinematics in both normal and scrambled point-light displays indicates that motion cues can be sufficient to recognize particular aspects of biological motion. This finding generally supports the approach of Mather and Murdoch (1994) to use motion cues for the recognition of gender and can be contrasted with earlier research that suggested the utility of configural cues in gender recognition (Cutting, 1978). However, the fact that a fair percentage of participants viewing the upside-down phase-scrambled displays still reported seeing some form of animate movement raises questions about the generalizability of formless motion cues. In particular, it is possible that the use of kinematics for perception of activation is contingent upon the attribution of animacy to a display (Tagiuri, 1960). Such a question lies on the seldom explored borders of research into animacy and biological motion (for a recent review on animacy see Scholl & Tremoulet, 2000).

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