Study of kinematics and eye movements during imitation

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1. Introduction and background

The study of imitation is of particular interest for the RobotCub project. Principles of human imitation are to be implemented in the humanoid artefact that will be created during the project. How the translation process from the perceived action to the executed action is accomplished during imitation is under discussion till now. On the one hand there are theories, which claim that imitation is a direct perceptual-to-motor mapping [1]. They consider imitation as the replica of the movements that are performed during the execution of the observed action. On the other hand there is the theory of goal directed imitation (GOADI), claiming that imitation is guided by cognitively specified goals [2]. According to this theory, imitation replicates the goal of the observed action, more than the single movements composing it. Consequently, action's kinematic details are imitated only if they represent the goal itself (e.g. during gestural communication). A newer idea claims that imitation is modulated by the justifiability of the observed goal-directed actions by the constraints under which they are executed [3].
The present study investigates the behavior of normal subjects during imitation in order to discriminate between these possibilities.

2. Methods

1. Participants

Ten subjects (6 women and 4 men, 24-30 years-old) volunteered to participate. All participants reported that they had normal or corrected-to-normal vision.

2. Paradigm

The subject and the demonstrator were seated one in front of each other (Fig. 1). Both transitive and intransitive actions were shown to the subjects. Transitive actions consisted of reaching for, grasping and lifting of an object. Intransitive actions consisted of placing the open hand onto different positions on the table. At the beginning of transitive actions trials, an object was present in front of both the subject and the demonstrator. At the beginning of intransitive actions trials, no objects were present. The movements were shown by the demonstrator with either normal kinematics or with higher reaching speed or with an abnormal elbow elevation.

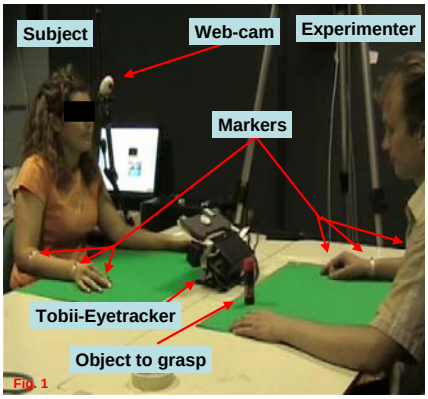


Fig. 1

Six different experimental conditions resulted:

A. grasping, with normal kinematics
B. grasping, with abnormal high elbow elevation
C. grasping, with higher reaching speed
D. intransitive movements, with natural kinematics
E. intransitive movements, abnormal high elbow elevation
F. intransitive movements, with higher reaching speed

Each condition was executed ten times and the trials were randomly mixed.

3. Eye tracking

Eye movements of the subjects were continuously tracked. The Tobii x50 eye tracker (see Fig.1) and the software ClearView 2.5.1 (Tobii Technology AB, Sweden) were used to record subjects' eye movements. The system emits infrared light and can determine the position of the pupil by the different reflection of this infrared light from the subject's retina and the iris.
A web-cam (see Fig.1) was used to record the stimuli presented during the experiment. The video was then used off-line, to overlap the gaze information of the subjects with the recorded stimuli (Fig. 2).
The behaviour of the subjects during observation of the demonstrator's movements was analysed qualitatively by examining which details of the stimulus the subjects were looking at during the various action phases


Fig. 2

4. Kinematics recordings

Kinematic parameters of the experimenter's and the subject's arm and hand movements were continuously recorded during the experiment. A system of three ProReflex MCU1000 cameras (QUALISYS, Sweden) was used to measure the position of infrared reflecting markers in the 3D space. Six markers were fixed on the arm and hand of the experimenter and of the subject (Figs. 1,2). Figure 3 shows a 3D reconstruction of the 6 marker traces during the movement of the subject. The maximum elbow elevation (MEE) and maximum wrist velocity (MWV) of the reaching component were calculated for the experimenter's and subject's movements.

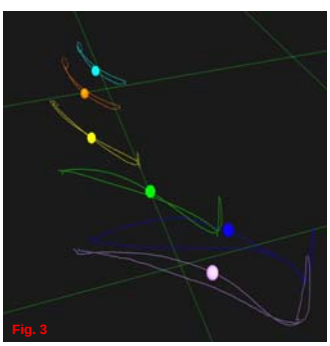


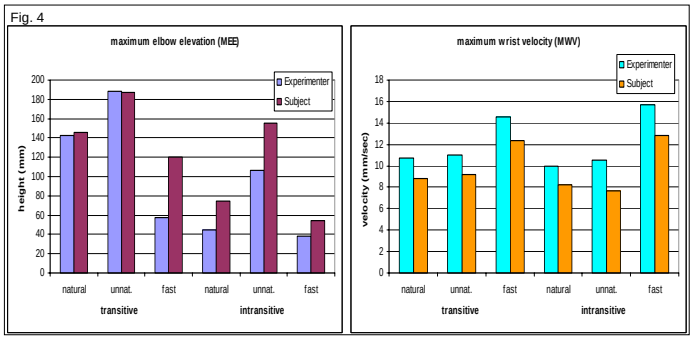
Fig. 3

3. Results

1. Results of kinematic recordings

The maximum elbow elevation (MEE) and the maximum wrist speed (MWV) during reaching were analysed. Figure 4 shows the mean values of MEE (left panel) and MWV (right panel) as recorded from the experimenter and from one representative subject in the various conditions.

Fig. 4



	MEE		MWV	
	normal vs. high elbow		normal vs. fast	
	transitive	intransitive	transitive	intransitive
Subj.1	-	xx	xx	-
Subj.2	xx	xx	xx	x
Subj.3	xx	xx	xx	xx
Subj.4	xx	xx	-	x
Subj.5	xx	xx	xx	xx
Subj.6	-	-	-	xx
Subj.7	xx	xx	xx	xx
Subj.8	xx	xx	xx	xx
Subj.9	xx	xx	xx	xx
Subj.10	xx	xx	xx	xx

Table1: 'x': 0.01<p<0.05; 'xx': p<0.01; '-': p>0.05

To test whether the subjects were significantly influenced by these two parameters during imitation, we compared subjects' MEE during the natural condition and the condition with abnormal elbow elevation (one-tailed t-test). The same test was used to compare subjects' MWV during the natural condition and that with higher reaching velocity. Table 1 shows the results for each analyzed subject.

Seven out of the ten subjects significantly imitated both the increased velocity and the abnormal elbow elevation, in both transitive and intransitive actions. The remaining three subjects were only partially influenced by demonstrator's kinematics,

2. Results of eye-tracking

Subjects significantly influenced by demonstrator's elbow elevation show a variety of gaze behaviors (Table 2). Three subjects (3,9,10) looked at the elbow since the beginning of the experiment. Two subjects (4,7) looked only at the hand or, in some cases, directed their gaze to the target, anticipating demonstrator's reaching movement. Two of them changed their strategy during the experiment, looking only occasionally at the elbow at the beginning of the experiment and more frequently at it during the last trials (2,8). Subject 1, which only partially imitated demonstrator's elbow elevation was never looking at the demonstrator's elbow. (face).
The remaining two subjects were excluded from analysis, due to recording artifacts.

Table 2	before movement start	at start of transport phase	during transport phase	at goal state	remarks
Subj. 1	hand, fingers	following or anticipating hand movement	following hand or looking at object	hand/object	in second half of experiment only looking at the face
Subj. 2	face, hand	face	face	face, hand/object	in second half of experiment behaviour changes, looking more at movement details
	face, hand, forearm	anticipating to object or follwing hand/elbow	following hand/elbow or looking at object	hand/forearm	
Subj. 3	hand, forearm, elbow	looking at hand/forearm/elbow	following hand/forearm/elbow	hand/forearm/elbow	looking in all phases at movement details
Subj. 4	hand	following hand	following hand	hand/object	always looking at the hand
Subj. 7	hand	following hand	following hand	hand/object	always looking at the hand, sometimes anticipating
Subj. 8	hand, face	anticipating/following hand; looking at face/object	follwing hand	hand, forearm, elbow	in second half of experiment behaviour changes, looking more at movement details
	face, object, looking around	object, elbow	object, elbow	object/hand, elbow, forearm	
Subj. 9	hand	following hand, sometimes anticipating	following hand, looking to elbow	mostly elbw	When target of reaching is almost achieved, gaze shifts to the elbow
Subj. 10	hand	anticipating/following hand	following hand, looking to elbow	mostly elbw	When target of reaching is almost achieved, gaze shifts to the elbow

Conclusion

The results indicate that, when the goal is known since the beginning, subjects replicate the goal of the action and imitate the complete pattern of kinematics parameters. A possibility could be that, in this particular situation, the kinematics used by the demonstrator to execute the action were considered the goal to be imitated, since there were no obvious reasons to modify them during the different trials [3]. Future studies will be necessary to investigate the influence of the ambiguity of the goal of the observed action in the imitation of different kinematics that are irrelevant to the action purposes.

References

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