



An experimental paradigm to compare motor performance under laboratory and under everyday-like conditions

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ABSTRACT

Research findings on human motor skills may not necessarily hold in everyday life, since laboratory and everyday scenarios typically differ with respect to the subjects' attention to the skill, their motivation to perform at their best, the goals they try to achieve, and the mode of movement initiation – extrinsic versus intrinsic. Here we present an experimental approach which can be used to substantiate the hypothesized effects of laboratory (L) versus everyday (E) settings on *one* type of motor skill, i.e., manual prehension. This approach is based on two tasks: In task L, subjects are told that they will participate in an experiment on grasping, and are instructed to seize and move a lever upon appearance of a visual target. In task E, they are told that they will play a computer game, and they have to seize and move the lever in order to proceed from one game level to the next. Both tasks include prehension movements from the same starting position and object to the same terminal position and object; movements differ only in their behavioural context. We exemplify the utility of our approach with a preliminary analysis of kinematic and force data. It shows that the two tasks differ with respect to several performance measures, and that some performance measures make independent contributions to that difference. The existence of independent contributions suggests that behavioural context may influence prehension via several distinct routes. Our approach can be used for comprehensive analyses of the context-dependence of motor skills in various reference groups.

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1. Introduction

It has long been recognized that the principles of motor control established in the laboratory may not necessarily apply in everyday life. For example, subjects instructed to grasp an instrumented dowel quickly and accurately with their thumb and index finger after hearing a beep, may move their hand differently than the patrons of a coffee shop who reach for a cup of espresso; these differences may exist even if cup and dowel have the same size, shape and egocentric location. This is not to say that laboratory findings are of limited value; on the contrary, they have yielded highly important insights into motor functions, their neural substrate, and their deficits in clinical cases. However, care must be taken when extending the conclusions reached in laboratory research to everyday scenarios such as workplace ergonomics or vehicle design.

Laboratory scenarios differ from everyday life in various ways. First, laboratory subjects are told that they participate in research on grasping, are fitted with sensors which connect by wires to recording equipment, and are instructed to move their arm in a specific fashion, e.g., quickly and/or accurately. In consequence,

their attention is likely to be closely focussed on the task, while in everyday life, it might be focussed elsewhere. This difference could well affect behavioural responses, since motor performance is known to depend on the focus of attention (Eversheim and Bock, 2002; Passingham, 1996; Posner, 1980). Second, laboratory subjects might be intimidated by high-tech research equipment and/or by the professional status of the experimenter; alternatively, they might be incited by the prospect to please the experimenter and/or to outperform other subjects. In either case, their motivation to perform at their best may be different than in real life, where mediocre performance is often sufficient: a cup must be picked up without spilling its contents, and not as precisely as possible. Again, different motivation levels are known to affect movement execution (Hsieh et al., 1996; Kleinsorge, 2001; Sarvia et al., 1989). Third, movements in the laboratory are executed for their own sake, while in real life they are typically subordinate to a higher goal, such as to stay alert by the effects of caffeine. Differences in goal setting are again known to modify behaviour (Daprati and Sirigu, 2006; Henry and Rogers, 1960; Symes et al., 2007). Fourth, laboratory movements are typically triggered by external cues and are repetitive, while everyday movements are often triggered by the person's own intentions and are preceded and followed by other behaviour. These differences were also shown to affect movement execution (Allport et al., 1994; Hyman, 1953; McCarley et al., 2003; Palmera et al., 2007; Stuss et al.,

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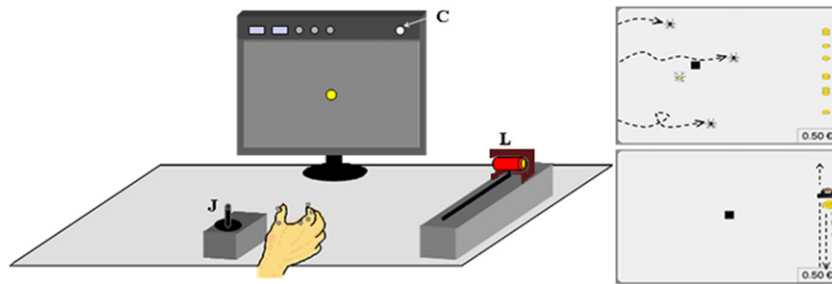


Fig. 1. Left: Experimental set-up with joystick (J), lever (L), monitor with concealed camera (C), and a subject's hand fitted with reflective markers. The monitor displays the visual target which triggered prehension movements in task L. Right: Screenshots from task E, showing the spider-chasing game with reward display (top) and the collection of rewards by a digger moving down the screen (bottom). The black square is the joystick-driven cursor for task E, and the dashed lines represent movement paths.

1995; Waszak et al., 2005). Thus summing up, literature provides several lines of evidence that motor performance in the laboratory may differ from that in real life.

The present work focuses on manual prehension, since it is a fairly complex yet well investigated motor act. Prehension consists of a transport component which brings the hand near the object of interest, and a grasp component which shapes the fingers in accordance with the object's size and form. These two components have different neural substrates and distinct kinematic features, but are issued in a coordinated fashion (Dubrowski et al., 2002; Jeannerod, 1981). Like pointing movements (Fitts, 1954), both components of prehension exhibit a speed-accuracy trade-off (Girgenrath et al., 2004). After the hand contacts the object, it applies grip and load forces to it with stereotyped profiles, allowing for a small safety margin of the grip over the load force (Johansson and Westling, 1984). The coupling of grip and load forces is highly automatized, but is flexible enough to compensate even for massive changes of the gravito-inertial environment (Hermsdörfer et al., 2000).

Since these and other principles of prehension were observed in laboratory settings, they may not hold in application areas such as workplace ergonomics and motor rehabilitation. In one laudable approach, therefore, an instrumented glove has been used to register hand gestures throughout subjects' daily routines (Ingram et al., 2008). The outcome provided valuable insights into the coupling of individual fingers during natural behaviour, but yielded no information about hand trajectories, and allowed no comparisons between similar movements executed once under everyday, and once under laboratory conditions. The purpose of the present work is to introduce procedures which avoid these shortcomings, and thus may be used to scrutinize the ecological validity of laboratory research. Our present communication is methodological, and contains only a limited amount of exemplary data. A comprehensive data analysis, and additional experiments which scrutinize the critical properties of the everyday versus the laboratory condition, will be communicated separately.

2. Method

2.1. Apparatus

The experimental hardware is shown in the left part of Fig. 1. Subjects sit in front of a 15" computer monitor and a regular (movement-operated) joystick, both centered about their body midline. At a distance of 46 cm to their right is a lever which slides fore-aft on a rail; this movement is limited to 3.5 cm by mechanical stops. Lever position is registered by a laser based position encoder (WayCon LAS-T500) with a resolution of 0.6 mm, and lever force is measured by a 6 df force transducer (ATI Nano 17) with a resolution of ± 0.006 N and ± 0.016 N m. The signals are sampled at 250 Hz by a 16-bit A/D converter (NI 6036E), i.e., the sampling accuracy is better than the analog resolution. Joystick position is registered via a

conventional USB port (60 Hz, 8-bit). The tops of joystick and lever are both 12 cm above the table, and the linear distance between the central position of the joystick and the distal position of the lever is 50 cm. Thus, to reach from the joystick to the lever, the hand must move in the horizontal plane 50 cm right- and forward, while increasing the grip aperture from 1.2 cm (joystick diameter) to 4.0 cm (lever width).

The positions of thumb and index finger are recorded by the Vicon®-MX-F20 3D optical motion capture system with a resolution of 1600×1280 pixels, and a sampling rate of 250 Hz. To this end, reflective wireless markers of 6 mm diameter are attached to both fingers with double-sided adhesive tape. A concealed video camera, located above the monitor, registers the subjects' face at 30 Hz; these data can be used to determine the subjects' gaze direction.

2.2. Procedures

In the laboratory task, subjects are told that they will participate in an experiment on grasping in which their hand position and lever force will be registered. They are instructed to hold the tip of the joystick between thumb and index finger and, whenever a visual target appears on the screen, to release the joystick, move the hand "naturally" to the lever, grasp it with thumb and index finger, slide the lever forwards and back again, and return the hand to the joystick. The joystick is immobilized in its central position for this task. The target is a yellow circle of 1 cm diameter, and is presented for 2 s in the center of the screen. Condition L consists of 22 trials, with intertarget intervals varying randomly between 2 and 6 s.

In the everyday-like task, subjects are told that they will play a computer game in which they chase spiders and earn €0.02 for each spider they catch. No instructions are given on how to move the hand. As depicted at the top right of Fig. 1, the game presents cartoon spiders which move across the screen from left to right; speed and complexity of this movement increases every fifth game level. When subjects contact a spider with a joystick-driven cursor, the spider disappears, and a coin is added at the right screen edge; spiders which are not contacted disappear at the right edge and no coin is added.

Each game level lasts 10 s. A green dot is then displayed in the screen center, prompting subjects to move the cursor – and thus the joystick – to the center. A digger is then displayed in the top right corner of the screen. Subjects now release the joystick, grasp the lever, and move it forward to move the digger down the screen, as shown at the bottom right of Fig. 1. Along its way, the digger collects all earned coins and deposits them in a vault at the bottom of the screen. The vault content is displayed on the screen throughout the task. The subjects then move the lever – and thus the digger – back to their starting positions, and thereafter return their hand to the joystick to start the next game level. The game terminates after 22

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