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Age-related differences in processing visual device and task characteristics when using technical devices

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ABSTRACT

With aging visual feedback becomes increasingly relevant in action control. Consequently, visual device and task characteristics should more and more affect tool use. Focussing on late working age, the present study aims to investigate age-related differences in processing task irrelevant (display size) and task relevant visual information (task difficulty). Young and middle-aged participants (20–35 and 36–64 years of age, respectively) sat in front of a touch screen with differently sized active touch areas (4″ to 12″) and performed pointing tasks with differing task difficulties (1.8–5 bits). Both display size and age affected pointing performance, but the two variables did not interact and aiming duration moderated both effects. Furthermore, task difficulty affected the pointing durations of middle-aged adults moreso than those of young adults. Again, aiming duration accounted for the variance in the data. The onset of an age-related decline in aiming duration can be clearly located in middle adulthood. Thus, the fine psychomotor ability "aiming" is a moderator and predictor for age-related differences in pointing tasks. The results support a user-specific design for small technical devices with touch interfaces.

1. Introduction

Controlling tools in technical environments challenge the human information processing system when disparate visual and proprioceptive/tactile feedback has to be integrated. For instance, the use of a computer mouse introduces a translational transformation: The relation between the amplitude of the hand operating the mouse (= proximal action effect) and the amplitude of the cursor on a display (= distal action effect) is not 1:1, but amplified by a gain factor. Consequently, proprioceptive/tactile feedback from the moving hand and visual feedback from the moving cursor do not correspond, and human information processing often becomes slow and inaccurate. This problem, which arises from indirect input devices, is alleviated by the increasing reliance on touch interfaces. The direct interaction with the finger or stylus allows faster and usually more accurate input than any indirect input device (for an overview see Douglas and Mithal, 1997).

In mobile technical devices, the size of the touch interface decreases resulting in a more restricted movement space that seems contradictory to an efficient interaction. For example, Tränkle and Deutschmann (1991) found 12% shorter movement times for aiming tasks presented on a large display compared to those presented on a small one. In their experiment display size was completely irrelevant for the visual-motor task. Although task difficulty (Fitts, 1954) was constant across all display sizes, movement times differed. The authors interpreted their finding as being of a cognitive nature: "We assume that a larger display caused the subjects to act in a more 'carefree' way and to move the mouse faster from the beginning, while with a smaller display an initially more careful approach was only gradually supplanted by confidence, without being overcome completely, in the course of the learning process" (Tränkle and Deutschmann, 1991, p.171). The subtle influence of display size (task-irrelevant visual information) on psychomotor performance has since been investigated in very few studies. Recently, Lai and Wu (2012, 2014), as well as Jakobsen and Hornbæk (2011), confirmed the effect of display size on motor behaviour. For cursor positioning tasks presented on 7″, 8.9″, 10.1″ or 11.6″ displays, task completion times were significantly higher for the 7″ display than for the larger displays (Lai and Wu, 2012, 2014). Jakobsen and Hornbæk (2011) found a similar pattern of

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results. They presented map navigation tasks on 7.34″, 22.07″ and 66.23″ displays, and again, task completion time was highest with the smallest display (15.1 s) and slightly – but significantly – differed between the medium (8.6 s) and the large display (8.8 s). It can be concluded that small displays (around 7″) indeed limit motor behaviour in the way Tränkle and Deutschmann first assumed in 1991.

These findings seem somewhat surprising from a theoretical point of view. In most of the above-mentioned studies (e.g., Tränkle and Deutschmann, 1991; Lai and Wu, 2012, 2014) task difficulty was constant across all display sizes. Thus, movement times should have been constant according to Fitts's law (Fitts, 1954). But this was not the case. For constant task difficulties small displays increased movement times (Tränkle and Deutschmann, 1991; Lai and Wu, 2012, 2014).

Fitts's law (Fitts, 1954) is the most prominent principle in motor control for goal-directed movements. According to Fitts, movement times for rapid aimed manual movements increase as a log linear function of task difficulty, i.e., the relation between target amplitude and target size. Numerous studies in the past decades have confirmed that Fitts's law (Fitts, 1954) also holds for varied direct and indirect input devices (for an overview see Douglas and Mithal, 1997). Fitts's law holds also for force-controlled input devices (e.g., isometric joystick; Sutter, 2007; Sutter et al., 2011) where users do not perform any ballistic hand movement but apply force to a force-sensitive surface in order to move a cursor on a display. How is this possible?

Cognitive approaches, the ideomotor principle for instance (Greenwald, 1970; James, 1890; for recent overviews of empirical evidence see, e.g., Hommel et al., 2001; Nattkemper and Ziessler, 2004), assume that any intentional act requires a goal that is an anticipatory representation of the intended action effect. The anticipation of action effects may fulfil a generative function in motor control. Actors select, initiate, and execute a movement by activating the anticipatory codes of the movement's effect. Thereby, representations of body-related effects (e.g., applying force to the isometric joystick) seem to be of minor relevance, but representations of the effective part of a tool (e.g., moving cursor on the display) predominate action control (e.g., Kunde et al., 2007; Janczyk et al., 2012; Müsseler and Skottke, 2011; Müsseler and Sutter, 2009; Wang et al., 2012; for a recent review see Sutter et al., 2013).

The impact of visual action effects on motor control has been clearly demonstrated in experimental setups that varied visual task characteristics only, while motor behaviour remained constant (e.g., Ladwig et al., 2013; Rieger et al., 2005; Sutter et al., 2008, 2011, 2012). Participants performed pre-defined hand movements on a covered digitizer tablet and received visual feedback on a display in front of them. Studies in our lab (Sutter et al., 2008, 2011, 2012) adapted a task introduced by Rieger et al. (2005). We presented two horizontally arranged target boxes on the display. Participants moved the cursor back and forth between the two boxes until they performed 25 error-free movements. We decoupled manual movements and visual cursor movements, and varied visual cursor amplitude and target size only. Hand amplitude on the digitizer tablet remained constant within a block. According to Fitts's law (Fitts, 1954), this keeps task difficulty for the hand movements constant, and randomly varies task difficulties for the cursor movements. What we found was an increase in movement times as a function of visual task difficulty. This supports that actions are planned and executed with regard to their distal (visual) effects (i.e., visual cursor amplitude and visual target size), not with regard to their proximal (proprioceptive/tactile) effects. It is this predominance of visual (distal) action effects that explains why Fitts's law applies also to cursor movements of force-controlled input devices where users do not longer perform any ballistic hand movement, but produce a ballistic cursor movement.

With aging, visual action effects become increasingly important in controlling goal-directed movements (e.g., Pratt et al., 1994; Seidler-Dobrin and Stelmach, 1998; Sutter et al., 2012). For rapid aiming, Pratt et al. (1994) investigated the impact of practice on movement kinematics in young and old adults (mean age 21 years and 66 years, respectively). Participants manipulated a handle to perform aiming movements with a cursor on a display. Target amplitude and size were always the same, and practice varied between 100 trials (exp. 1) and 200 trials (exp. 2). Young adults modified movement kinematics through practice (from mostly visually controlled to mostly pre-programmed), but old adults did not. The latter continued to control their movements visually, and even an extension of practice (exp. 2) did not result in any adjustments of motor behaviour.

Visual action effects become increasingly important with age, even if visual information is irrelevant to the task: Wang et al. (2012) investigated the perception of hand movements with disturbed visual feedback and without visual feedback (control condition). Young and old adults (mean age 25 years ($SD = 2.7$) and 67 years ($SD = 4$), respectively) sat in front of a robot arm. They placed their dominant hand on a handle attached to the tip of the robot arm; while a cover blocked their direct view of the hand and the robot arm. The robot produced one of six pre-defined trajectories in the shape of an acute ($\gamma = 45°$ or $63°$ or $81°$) or an obtuse triangle ($\gamma = 99°$ or $117°$ or $135°$). Triangles were isosceles with a constant horizontal base of 26 cm. Participants were instructed to follow the movement of the robot arm with their hand on the handle and to monitor their hand movement very carefully. During the movement participants received perturbed visual feedback on a display. The cursor produced a static equilateral right-angled triangle (horizontal base = 26 cm). The cursor movement was synchronized with the robot arm's movement. In the control condition they did not receive any visual feedback. After the completion of a movement participants were asked to evaluate the shape of their hand movement (acute or obtuse) by giving a verbal response. With perturbed visual feedback participants became uncertain about their hand movement. This was more pronounced for old than for young adults. The authors concluded that the presence of visual action effects attenuated hand perception. And, old adults relied more on visual feedback – or in other words – they were less able to ignore it than young adults. The latter finding is in line with the inhibition deficit hypothesis by Hasher and Zacks (1988) that assumes a weakening of inhibitory control with age. It is also in accordance with the concept of field dependence (e.g., Witkin and Asch, 1948a, b). Field dependence is assumed to be a trait wherein we perceive the outer world by using internal (field independent) or external frames of reference (field dependent). A number of studies have found age-related differences in field dependence: Old adults are more field dependent than young adults (e.g., Cohen and Axelrod, 1962) as they rely more on environmental information.

As demonstrated above, the increased reliance on visual feedback is clearly apparent in old adults (old adulthood: 65 + years of age; cf., Erikson, 1950). However, the onset for this change in visual information processing might be assigned to middle adulthood (middle adulthood: 40–65 years of age; cf., Aiken, 1998; Erikson, 1950). Several studies comparing young and middle-aged adults have demonstrated small, but significant, age-related differences in visual action effect control (Armbrüster et al., 2007; Sutter et al., 2012). However, these were all visual-motor tasks in which visual information was task relevant. Thus, the present study aims at uncovering the impact of task-irrelevant visual information and investigates the onset of age-related difference in visual action effect control. Participants perform pointing actions on a differently