Journal of Experimental Child Psychology 105 (2010) 116–129

Contents lists available at ScienceDirect

Journal of Experimental Child Psychology

journal homepage: www.elsevier.com/locate/jecp

Developing motor planning over ages

Jean-Pierre Thibaut [a,*], Lucette Toussaint [b]

[a] Department of Psychology, LEAD-CNRS, Université de Bourgogne, 21065 Dijon, France
[b] CeRCA-CNRS, Université de Poitiers, 86000 Poiters, France

ARTICLE INFO

Article history:
Received 5 August 2009
Revised 4 October 2009

Keywords:
Motor development
Motor planning
End-state comfort effect
Primary school children
Kindergarteners
Objects and tools

ABSTRACT

Few studies have explored the development of response selection processes in children in the case of object manipulation. In the current research, we studied the *end-state comfort effect*, the tendency to ensure a comfortable position at the end rather than at the beginning of simple object manipulation tasks. We used two versions of the unimanual bar transport task. In Experiment 1, only 10-year-olds reached the same level of sensitivity to end-state comfort as adults, and 8-year-olds were less efficient than 6-year-olds. In each age group, children's sensitivity did not increase during a session: i.e., either clearly showed the sensitivity or showed no sensitivity at all. Experiment 2 replicated these results when the bar was replaced by a pencil and when the task did not require much precision. However, when the task required more precision, 8-year-olds increased their level of sensitivity to the end-state comfort effect, whereas this was not the case for younger children. These results describe the development of advanced planning processes from 4 to 10 years of age as well as the positive effect of task constraints on the end-state comfort effect for 8-year-olds.

Introduction

Most usual objects we use in the real world can be grasped, a priori, in numerous manners. For example, picking up a pair of scissors could be done by either of the two handles or even by the cutting end. However, depending on the *purpose* of the action, certain types of grasps are more efficient than others. In the case of scissors, to cut a piece of paper we would take the scissors by the two handles,

* Corresponding author.
E-mail address: jean-pierre.thibaut@u-bourgogne.fr (J.-P. Thibaut).

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doi:10.1016/j.jecp.2009.10.003

whereas we might grab them by the end of the cutters to give them to somebody else who wants to use them to cut some piece of paper. Or, if we want to convey a spoonful of syrup to our mouth, we would grab it overhand, with the right hand and with the thumb pointing down, if the bowl of the cup is pointing to the left. By contrast, we would grab the spoon handle overhand, with the left hand, if its bowl is pointing to the right, or we might grab it underhand, with the right hand and with the thumb in an upward location and the index finger in a downward location, and then rotate the wrist counterclockwise to convey the bowl to the mouth. These examples suggest that, among the many ways an object can be carried, only a subset of them are really comfortable (and, in the examples above, are safe for our shirts or outfits) and that efficient actions require accurate movements. In the motor control literature, determining how a movement or a combination of movements is chosen from the many available possibilities is referred to as the *degrees of freedom problem* (Bernstein, 1967). When a person consistently selects a specific action pattern when many movement options are available, one may infer that this combination of movements was planned in advance with respect to the goal.

One major constraint on movement selection is the *end-state comfort effect* (Cohen & Rosenbaum, 2004; Fischman, 1998; Fischman, Stodden, & Lehman, 2003; Lam, McFee, Chua, & Weeks, 2006; Rosenbaum & Jorgensen, 1992; Rosenbaum, van Heugten, & Caldwell, 1996; Rosenbaum et al., 1990; Weigelt, Kunde, & Prinz, 2006). The effect illustrates the tendency to ensure a comfortable position at the end of manual object manipulation rather than at the beginning when picking up a tool or kitchen utensil. It has also been reported that prehension of a particular object specifically changes as a function of what participants intend to do with it (Marteniuk, MacKenzie, Jeannerod, Athenes, & Dugas, 1987; Rosenbaum et al., 1990). A popular task used to investigate this phenomenon is the unimanual bar transport task, in which participants use either an overhand or underhand grip to pick up a bar lying horizontally on supports before placing its left or right end on a flat disk laid on either the left or right of the bar (Fischman, 1998; Rosenbaum, Vaughan, Barnes, & Jorgensen, 1992; Rosenbaum et al., 1990) or placed at different heights (Rosenbaum & Jorgensen, 1992; Short & Cauraugh, 1997). The authors observed that adults spontaneously switched strategies (overhand vs. underhand grip) depending on which end of the bar was to be brought to the target disk. Thus, it appeared that the postures that participants adopted on taking hold of the bar depended on what they planned to do with it because they anticipated their future bodily states. Researchers generally attributed a functional advantage of end-state comfort in the sense that ending in a comfortable posture would maximize control over the fine positioning movements needed during the final phase of the positioning task or would facilitate subsequent movement production. Some researchers observed that adults selected more comfortable end states and thus minimized awkwardness when the precision requirements of the task were greater (Rosenbaum et al., 1990, 1996; Short & Cauraugh, 1999). Rosenbaum and colleagues (1996) also reported that the end-state comfort effect vanished for some participants when the final positioning did not demand precision (see also Rosenbaum, Cohen, Meulenbroek, & Vaughan, 2006, for a review).

There is a large body of literature regarding grip adaptation in the neuropsychological literature (Carey, Harvey, & Milner, 1996; Dijkerman, Milner, & Carey, 1998; Goodale, Milner, Jakobson, & Carey, 1991) and in the developmental psychology literature. For example, Newman, Atkinson, and Braddick (2001) combined preferential reaching, preferential looking, and kinematic measures to study the development of infants' adaptation to the size of an object while reaching it. The results revealed that between 8.5 and 12 months of age, children developed sensitivity to the size of objects; they preferred to reach for graspable objects even though these were visually less salient than larger objects. According to the authors, these results would suggest an emerging ability to override the initial strong coupling between eye and hand movements (see Gauthier & Mussa-Ivaldi, 1988).

Recently, some authors have used the end-state comfort effect to study the planning of manual movement of infants and children (Adalbjornsson, Fischman, & Rudisill, 2008; Manoel & Moreira, 2005; McCarty, Clifton, & Collard, 1999, 2001). However, they observed inconsistent results. For example, Manoel and Moreira (2005) studied the sensitivity to end-state comfort of 2.5- to 6-year-olds in low- and high-precision tasks. Children needed to pick up a wooden bar and insert one of its distal parts into a hole in a box either cylindrical (low-precision condition) or semicylindrical (high-precision condition). They exhibited little evidence of end-state comfort or advanced planning ability in that study regardless of the precision required. Rather, the way they picked up the bar indicated strong