Interactive Coin Addition: How Hands Can Help Us Think

Hansjorg Neth and Stephen J. Payne

(CogSci 2011 Proceedings)

Paper Review

Hemangini Parmar (Y8214)

Introduction:

'A complementary strategy can be defined as any organizing activity which recruits external elements to reduce cognitive loads',(*Kirsh, D. ,1995*)

For instance, we use pencil and paper to add up big numbers. Here the pencil and paper play external elements. These elements help us save the cognitive task of storing carry overs and the incremental sums and fasten the task of adding. Human beings have always discovered techniques to simplify the information entering their brains and thus enhance their cognitive ability. In an experiment conducted by David Kirsh, he shows upside down photographs to the subjects and asks them to identify the person. It is observed that every one turns the picture back to normal position in order to recognize the person in the picture. This experiment proves that to facilitate perception, we perform certain actions which help us adapt the world to our perceptual capacities. Kirsh concludes that human beings prefer solving the cognitive problem by "adapting the world rather than adapting oneself"

In this paper, the authors decided to use virtual representations of the physical coins that could be moved on a computer screen by a mouse operated drag and drop operation to record complete behavioral protocols and analyze the movements involved in the task of counting in detail. Through this experiment, they were also able to answer one major question of 'agency', i.e. does their exist some structures which simplify the task? This they did by providing some subjects with the result of someone else's interaction.

Summary:

Sixty participants were randomly placed in basically two groups:-

1. <u>Interactive mode</u>: This mode was subdivided into two conditions:
   Move= the participants were free to move coins by using drag-and-drop;
   Look= the participants were only allowed to view the coins and count them
   (Note: To prevent the use of cursor as a pointing device, it was hidden within the display area)

2. <u>Configuration mode</u>: This mode was subdivided into two conditions:
   Initial= coins were scattered pseudo randomly(constraint being that two coins do not overlap);
   Final= the result of someone else's manipulations were given as initial configuration

Table 1: <u>Overview of the four experimental groups</u>

Configuration	**Interactive mode**	
	move	look
Initial	1: Initial-move	2: Initial-look
Final	4: Final-move	3: Final-look

Fig: Example screen display of an initial configuration

Hypotheses: They proposed that the move condition provided the users with a set of functions which helped them re-structure the mathematical properties of the task, (e.g. by grouping the coins of the same denomination (v) together, they could convert addition of n identical values into simple multiplication n.v) and thus enhance the performance of the users compared to their look condition counterparts. They also hypothesized that the goal of movement could be to 'mark' the counted coins or to 'sort' coins into clusters.

Result:

1. Performance was observed as in Table2. It was concluded that the initial lookers, i.e. the users who were given the initial configuration and subjected to look condition were the least accurate in counting.
2. Latency was observed as in Table3. Latency was analyzed in terms of time to complete the required number of correct trials. It was concluded that the speed of users was determined by the configuration given to them (the users who were given final configuration were faster than those with initial configuration; 19.1s vs. 27.3s) while the interactive mode hardly had any impact (both move and look condition users finished their tasks in almost similar times; 24.3s vs. 22.2s)

Table 2: Addition accuracy: Mean number (Standard deviation) of errors in counting

Configuration	Interactive mode	
	move	look
Initial	5.27(3.56)	11.33(6.49)
Final	4.93(3.99)	6.20(3.65)

Table 3: Addition latency: Mean trial times(standard deviations) for correct additions

Configuration	Interactive mode	
	move	look
Initial	29.4(8.0)	25.2(6.1)
Final	19.1(6.0)	19.2(6.1)

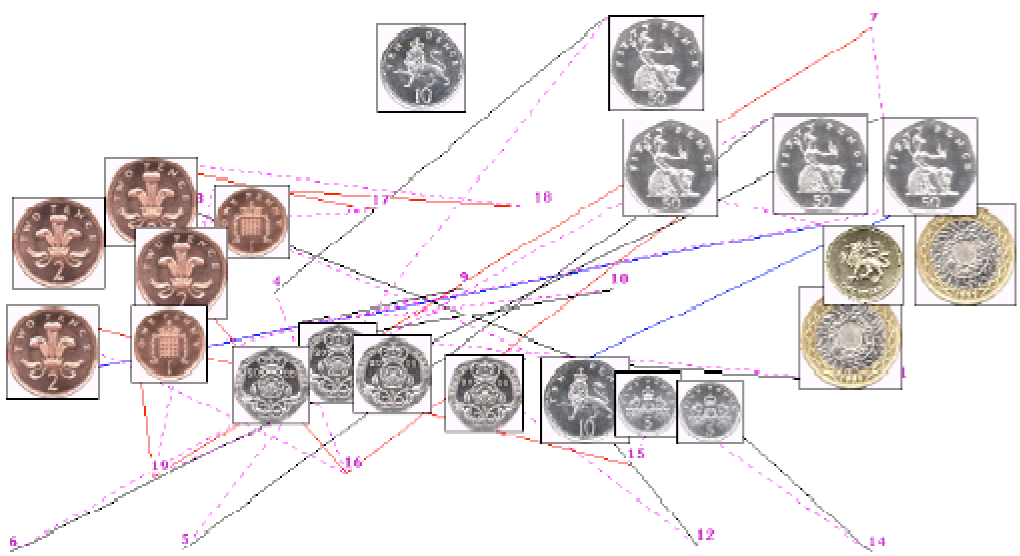

Fig: Screen diplay of a final configuration

(Thin solid lines indicate coin moves; dashed lines indicate distances between moves)

Discussion: This paper was successful in proving the hypotheses presented by the authors, first being that interaction has additional benefits (mathematical simplification) on the performance of a cognitive task. It was observed that in the process of counting, the users either created clusters of identical values or of the same round values. This result proved the second hypothesis that the coins were 'sorted' based on their values and not 'marked' by their location. As shown in the figure below, the procedure followed by the movers was not optimizing the distance their eyes or hands travelled between subsequent pick-up and drop-off positions of the coins instead the users followed a step-wise fashion while selecting the higher value coins first, followed by the coins of identical or lower value. An important result obtained from their experiment was that an inverse relationship was observed between the amount of movements by initial and final movers showing not only a high degree of adaptiveness in their actions, but the existence of the concept of a 'good' configuration.

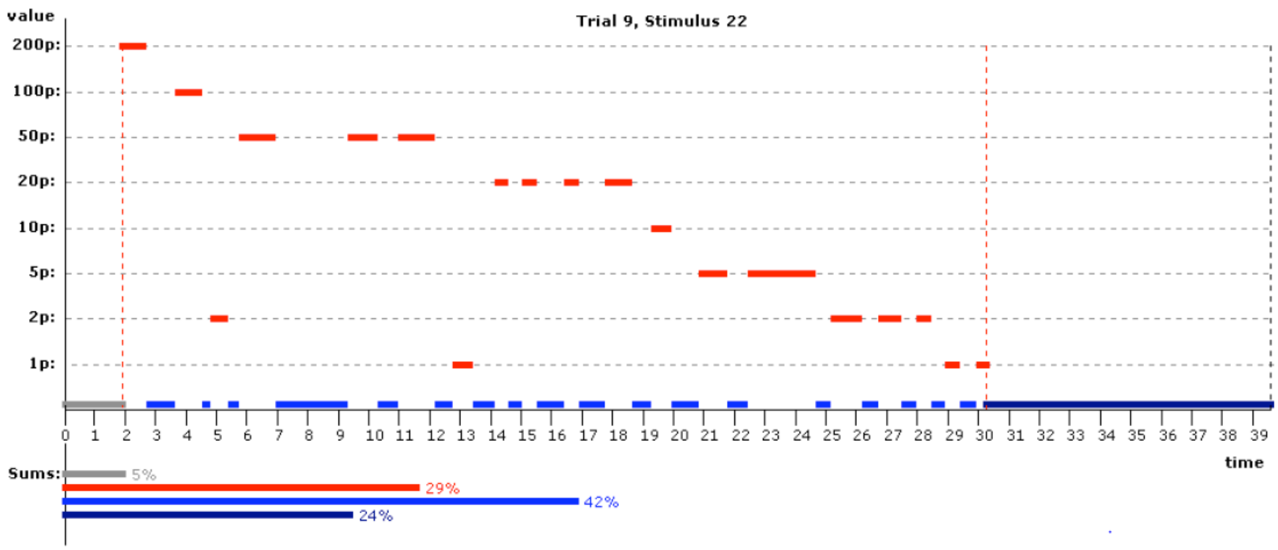

Fig: Plot of selected coin value v/s elapsed time; shows downward step function

Conclusion & other recommendations: This experiment revealed some unanticipated results such as the ability to move the coins, increased the accuracy but not the speed of additions (Table 2,3). This result was in contrast with the result presented by Kirsh(1995) who had stated that direct interaction enhanced both accuracy and speed. However these results were also incapable of explaining a very popular hypothesis that the users have to trade amongst speed and accuracy while interacting. The authors believe that external elements do help in reducing the cognitive load and that this is no more a black box situation, i.e. the question that 'How' does the interactivity actually facilitate task is no more mere 'magic' but the re-structuring of the task done by concrete means into more manageable steps.

However there have been many contradictory results regarding the effects of interactivity in visual-spatial tasks. There could be several possible reasons for it, one among them is interactive users being able to manipulate the system have more visual information compared to the non-interactive users. In many studies, there is no such variability in information provided to the non-interactive users. On the other hand, while the non-interactive users are provided with a selected list of operations, interactive users have to discover the most optimum way to manipulate the system to accomplish the task, which might not be achieved by all those who are allowed to interact (Keehner et. al,2008). According to the current theories given for interactive behavior, “Cognitive processes occur both internally (in the mind) and externally (in the world, within some external medium)” - (Hutchins, 1995; Zhang & Norman,1994).

“External representations are not merely peripheral aids to cognition; they intersect with internal representations to form a distributed representational space for solving a problem” -(Keehner et. al,2008)

Keehner et. al (2008) conducted an experiment which involved inferring and drawing a cross-section of an unfamiliar 3-D object. They concluded that “there are individual differences in how effectively people use these visualizations and the extent to which they offload cognition onto these external aids, rather than performing internal computations. As a result, different individuals receive different visual information from external visualizations, and in the end what matters is whether they access the key task-relevant information, not whether they had active control”. There have been some views about benefits from interactivity like since the users are independent of interacting with the interface, they could perform the relevant movement at their own time so that it got coupled with their internal cognitive processes (cf. Hollan, Hutchins & Kirsh,2000), and that interactivity sets up a correspondence between the motor commands and the consequent movements. Some authors believe that since the interactive users are able to monitor their motor commands corresponding to the spatial movements, they in a way learn especially strong cues about spatial properties (e.g., Christou & Bulthoff, 1999; Feldman & Acredolo, 1979; Philbeck, Klatzky, Behrmann, Loomis, & Goodridge, 2001; Wang & Simons, 1999). Whereas in case of a non-interactive visualization, the user might be provided with some of the most task relevant views of the object but not necessarily at the time when they are ready to process that information. According to a recent research, in case of naturalistic interfaces (in which the manipulations are exactly replicated in the movements of the visualizations), “congruent” hand motions could facilitate and “incongruent” hand motions could hamper mental rotation. (Wexler, Kosslyn & Berthoz, 1998; Wohlschlager & Wohlschlager,1998; but see Schwarz & Holton, 2000).

Literature cited:

- Kirsh, D. (1995). Complementary strategies: Why we use our hands when we think. In Proceedings of the 17th Annual Conference of the Cognitive Science Society (pp. 212-217).Hillsdale, NJ: Lawrence Erlbaum.
- Keehner, M., Hegarty, M., Cohen, C., Khooshabeh, P., & Montello, D. R. (2008). Spatial reasoning with external visualizations: What matters is what you see, not whether you interact. Cognitive Science, 32, 1099-1132.
- Hutchins, E. (1995). How a cockpit remembers its speed. Cognitive Science, 19, 265-288.
- Zhang, J. & Norman, D.A. (1994). Representations in distributed cognitive tasks. Cognitive Science, 18, 87-122.
- Hollan, J., Hutchins, E., & Kirsh, D. (2000). Distributed cognition: Toward a new foundation for human-computer interaction research. ACM Transactions on Computer-Human Interaction, 7(2), 174-196.
- Christou, C. G., & Bulthoff, H. H. (1999). View dependence in scene recognition after active learning. Memory & Cognition, 27, 996-1007.
- Feldman, A., & Acredolo, L. P. (1979). The effect of active versus passive exploration on memory for spatial location in children. Child Development, 50, 698-704.

- Philbeck, J. W., Klatzky, R. L., Behrmann, M., Loomis, J. M., & Goodridge, J. (2001).Active control of locomotion facilitates nonvisual navigation. Journal of Experimental Psychology: Human Perception and Performance, 27, 141-153.
- Wang, R. X.-F., & Simons, D. J. (1999). Active and passive scene recognition across views. Cognition, 70, 191-210.
- Wexler, M., Kosslyn, S. M. & Berthoz, A. (1998). Motor processes in mental rotation.Cognition, 68, 77-94.
- Wohlschlager, A., & Wohlschlager, A. (1998). Mental and manual rotation. Journal of Experimental Psychology: Human Perception and Performance, 24, 397-412.
- Schwartz, D. L. & Holton, D. L. (2000). Tool use and the effect of action on the imagination. Journal of Experimental Psychology: Learning Memory and Cognition, 26, 1655-1665.