AGE-RELATED DECLINE IN COGNITIVE FLEXIBILITY

IMPLICATIONS FOR ICONOGRAPHIC INTERPRETATIONS IN USER INTERFACES

Research Overview by Adrian Wong

UNIVERSITY OF TORONTO

INTRODUCING COGNITIVE FLEXIBILITY

Cognitive flexibility refers to one's ability to switch from one mental process, set of information, or cognitive perspective, to another. It allows one to think of problems from multiple perspectives. It is an important higher-level executive function that allows one to behave in ways consistent with their goals. Being able to utilize this skill effectively is associated with many functional benefits, such as a higher quality of life in older adults and a higher resilience to negative life events and stress (Dajani and Uddin, 2017).

However, an aspect of age-related cognitive decline involves greater difficulties with cognitive flexibility. This can manifest itself in issues with perseveration, or an insistance on habitual behaviours even when they result in maladaptive outcomes. This has important implications with daily interactions, including those within digital interfaces. As such, it is important to study cognitive flexibility in relation to typical aging, especially in the context of traditional usability research (Davis et al., 2010).

EVIDENCE OF REDUCTION BY TYPICAL AGING

Cognitive flexibility is often associated with other executive functions such as working memory and attention. One must first direct attention towards particular aspects of a situation to know that a switch in behavior is necessary. Next, one must remember the proper behaviors associated with such a situational change. Finally, one must inhibit particular habits to avoid persisting behaviors that may be maladaptive in the new context (Dajani and Uddin, 2017).

Perry et al. (2009) noticed a significant decline in TMT-B scores as a function of healthy aging. Their research suggests that specific white matter tracts that connect frontal to more posterior regions are associated to TMT-B performance. The connectivity of most of these white matter tracts are also shown to have a negative correlation with age.

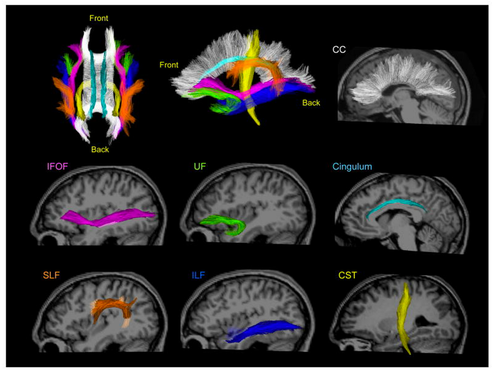


FIG.1 From Perry et al., 2009. There was a significant age related decline in the inferior fronto-occipital fasciculus (IFOF), uncinate fasciculus (UF), superior longitudinal fasciculus (SLF), and corpus callosum (CC). The white matter integrity of these areas (plus the inferior longitudinal fasciculus (ILF)) were correlated to performance on TMT-B.

Are we certain this data suggests a decline in cognitive flexibility by a function of typical aging, and not the result of some cohort effect? A study by Wecker et al. (2005) compared the scores of three cognitive flexibility measures between participants of various ages.

Across the D-KEFS Verbal Fluency Test, the D-KEFS Design Fluency Test, and the D-KEFS Trail Making Test (a modified version of the traditional Trail Making Test mentioned above), performance was negatively correlated with age. This age effect persisted even after controlling for education level, gender, IQ, and component skills that were specific to each test. These findings provide evidence that cognitive flexibility declines by a function of typical aging, independent of other related variables (Wecker et al., 2005).

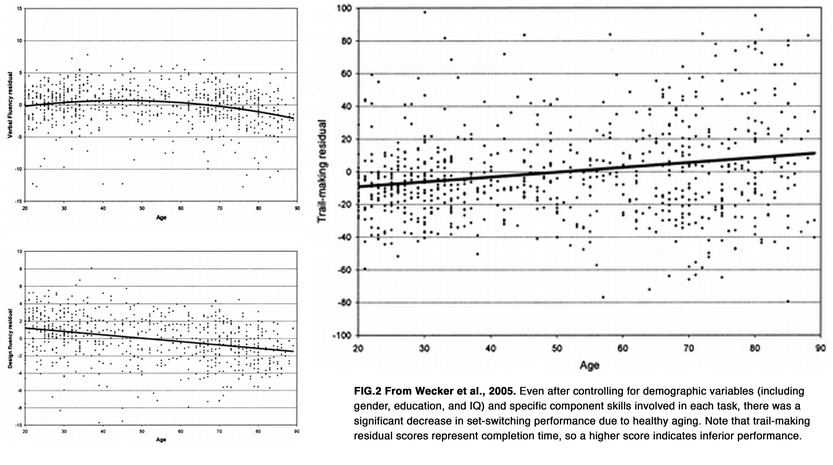


FIG.2 From Wecker et al., 2005. Even after controlling for demographic variables (including gender, education, and IQ) and specific component skills involved in each task, there was a significant decrease in set-switching performance due to healthy aging. Note that trail-making residual scores represent completion time, so a higher score indicates inferior performance.

IMPLICIT AREAS OF FUNCTIONAL DECLINE

FREE RECALL THROUGH CLUSTERING STRATEGIES

Just as working memory is necessary for cognitive flexibility, cognitive flexibility has particular implications for memory as well. Clustering is a strategy that works by the categorization of information such that it becomes easier to commit to memory. Cognitive flexibility is a necessary function for the effective use of this strategy. As such, older populations are less likely to use clustering. Even when clustering is used, its organizational benefits for free recall seem to be hindered as a function of age (Taconnat et al., 2009).

	Younger (n = 62)	*Older (n = 58)*	*t(118)*
Clustering (ARC)			
First trial	0.70 (0.28)	0.39 (0.25)	6.16*
Second trial	0.74 (0.24)	0.65 (0.32)	1.53
Third trial	0.84 (0.21)	0.79 (0.29)	1.06
Recall			
First trial	0.64 (0.10)	0.46 (0.15)	7.47*
Second trial	0.64 (0.11)	0.32 (0.15)	12.78*
Third trial	0.63 (0.11)	0.34 (0.16)	11.26*

TABLE 1 From Taconnat et al., 2009. Older participants performed worse than younger participants across recall trials and in cognitive flexibility measures. Clustering only improved recall scores for younger participants. Cognitive flexibility (as opposed to categorical fluency and processing speed) was the variable that was most related to effective clustering. As such, they predict that diminished cognitive flexibility in the elderly hinders the benefits of using clustering strategies for free recall.

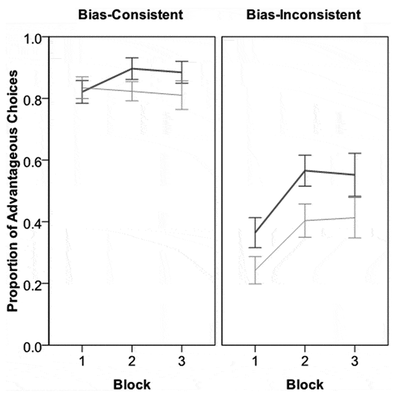


FIG.3 From Wilson et al., 2018. Older adults made less advantageous bias-inconsistent decisions than younger adults. Since older adults were able to decrease bias-driven decisions, they were able to display cognitive flexibility to some extent. However, this was to a lesser degree than the younger adults, who were better able overcome pre-existing bias in order to make advantageous decisions. As such, older adults were less able to learn (through outcome feedback) the average value of the riskier alternative and had more difficulty overcoming bias.

OVERCOMING PRE-EXISTING BIAS

Cognitive flexibility involves strategic adaptation to decision making processes that produce more advantageous outcomes. As a result, cognitive flexibility is necessary for overcoming pre-existing biases in order to learn new strategies or concepts.

When given the option to chose a definite outcome versus a risky gamble, older participants were slower to overcome the pre-existing bias that a sure gain always lead to a more profitable outcome or that a risky choice was always better than a sure loss. On the other hand, younger individuals were more flexible in their decisions and were more capable of learning through outcome feedback, thus overcoming such a pre-existing bias (Wilson et al., 2018).

INFORMATION QUERYING AND PROBLEM SOLVING

Usually, being unsuccessful calls for a reevaluation of the current strategy. In the context of information searching, being unable to find an appropriate answer merits the reformulation of the search query. Older individuals are less successful in answering various questions because they were unable to look for answers using different keywords. This is an interesting finding, given that older individuals have larger vocabularies and used as many keywords in their queries as their younger counterparts (Dommes et al., 2011).

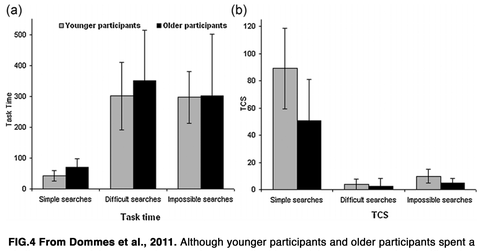


FIG.4 From Dommes et al., 2011. Although younger participants and older participants spent a similar amount of time answering questions overall, older participants answered a significantly lower percentage of questions correctly and also had a lower search performance indicated by task completion speed (TCS, the number of questions answered correctly per hour).

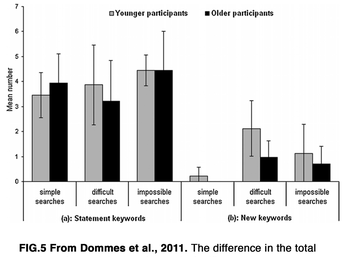


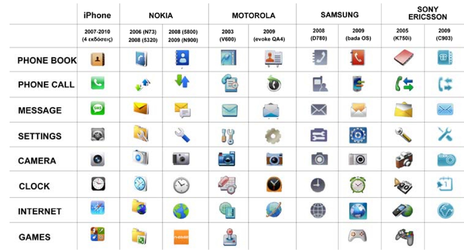
FIG.5 From Dommes et al., 2011. The difference in the total number of search keywords was insignificant across age groups, yet younger participants formulated a greater number of new keywords in their searches compared to older participants.

FLEXIBLE ICON RECOGNITION AND USABILITY

AGE-RELATED DIFFERENCES IN PREFERENCE AND INTERPRETATION

It has been demonstrated by previous literature that older participants seem to be less accurate in their ability to recognize and interpret icons in user interfaces (Gatsou et al., 2012). Several characteristics of iconography have been shown to mediate this age-related effect, such as the icon's level of concreteness, complexity, and discriminability (McDougall et al., 2000).

Furthermore, research by Cho et al., (2015) demonstrated an age-related preference for skeumorphic versus flat icon designs. Analysis revealed that subjective ratings of aesthetic quality was dependent on the degree of realism afforded by the skeumorphic design, while the level of abstraction influenced how understandable the icon was. For elderly users, icon realism can influence understandability and preference.



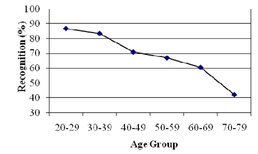
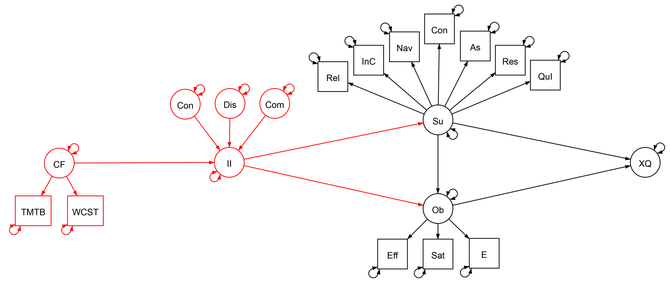


FIG.6 and FIG.7
From McDougall et al., 2000 and Gatsou et al., 2012.
Many icons can be used to represent a single function, and a single icon can be interpreted in many ways.
Age seems to be a factor that reduces accuracy in correctly recognizing and interpreting icon functionality.

PROPOSED COGNITIVE MODEL

Previous research has focussed its efforts on identifying specific design patterns when describing icon usability, but none have demonstrated a definitive link to cognitive research. It is argued that since icons are visual metaphors representing a particular action and can nevertheless be interpreted in many ways depending on interface contexts, cognitive flexibility is a higher-level executive function that mediates this process. Through cognitive flexibility (as measured by the TMT-B and WCST), one can afford expectational leniency when interacting with visual iconography. This leads to a better understanding of icon functionality, which is known to be important for both subjective and objective ratings of usability. Collectively, these two ratings of usability strongly influence the overall quality of the user experience (Nikov et al., 2006).



A HUMAN-CENTERED SOLUTION

In an analysis of the age-related preferences between social media interfaces, Strauss found that older users had a strong preference for Facebook while younger users had a strong preference for Snapchat (2018). In context with the proposed model, this is understandable given that Facebook (traditionally used on browsers) places more emphasis on textual information while Snapchat (traditionally used as a mobile application) places more emphasis on icons and visual metaphors.

When designing user interfaces for an elderly demographic in particular, it is important to understand the user from a cognitive perspective. Further research that would substantiate this proposed cognitive model would allow designers to take a more human-centered approach in addressing interface usability.

REFERENCES

Cho, M., Kwon, S., Na, N., Suk, H., & Lee, K. (2015). The Elders Preference for Skeuomorphism as App Icon Style. *CHI Extended Abstracts*.

Dajani, D. R., & Uddin, L. Q. (2015). Demystifying cognitive flexibility: Implications for clinical and developmental neuroscience. *Trends in Neurosciences*, *38*(9), 571–578. doi:10.1016/j.tins.2015.07.003

Davis, J. C., Marra, C. A., Najafzadeh, M., & Liu-Ambrose, T. (2010). The independent contribution of executive functions to health related quality of life in older women. *BMC Geriatrics*, *10*, 16. doi:10.1186/1471-2318-10-16

Dommes, A., Chevalier, A., & Lia, S. (2011). The role of cognitive flexibility and vocabulary abilities of younger and older users in searching for information on the web. *Applied Cognitive Psychology*, *25*: 717-726. https://doi.org/10.1002/acp.1743

Gatsou, C., Politis, A., & Zevgolis, D. (2012). The Importance of Mobile Interface Icons on User Interaction. *IJCSA*, *9*(3), 92-107.

McDougall, S. J., de Bruijn, O., & Curry, M. B. (2000). Exploring the effects of icon characteristics on user performance: The role of icon concreteness, complexity, and distinctiveness. *Journal of Experimental Psychology: Applied*, *6*(4), 291.

Nikov, A., Zaim, S., & Oztekin, A. (2006). Usability evaluation of web services by structural equation modeling.

Perry, M. E., McDonald, C. R., Hagler, D. J., Jr, Gharapetian, L., Kuperman, J. M., Koyama, A. K., ... McEvoy, L. K. (2009). White matter tracts associated with set-shifting in healthy aging. *Neuropsychologia*, *47*(13), 2835–2842. doi:10.1016/j.neuropsychologia.2009.06.008

Strauss, T. (2018, June 26). Young people can't use Facebook, old people can't use Snapchat - why? Retrieved from https://uxdesign.cc/young-people-cant-use-facebook-old-people-can-t-use-snapchat-why-f3305f011de1

Taconnat, L., Raz, N., Toczé, C., Bouazzaoui, B., Sauzéon, H., Fay, S., & Isingrini, M. (2009). Ageing and organisation strategies in free recall: The role of cognitive flexibility. *European Journal of Cognitive Psychology*, *21*(2-3), 347-365. http://dx.doi.org/10.1080/09541440802296413

Wecker, N. S., Kramer, J. H., Hallam, B. J., & Delis, D. C. (2005). Mental flexibility: Age effects on switching. *Neuropsychology*, *19*(3), 345-352. doi:http://dx.doi.org.myaccess.library.utoronto.ca/10.1037/0894-4105.19.3.345

Wilson, C. G., Nusbaum, A. T., Whitney, P., & Hinson, J. M. (2018). Age-differences in cognitive flexibility when overcoming a preexisting bias through feedback. *Journal of Clinical and Experimental Neuropsychology*, *40*(6), 586-594. doi:10.1080/13803395.2017.1398311