Do Make me Think!

How CUIs Can Support Cognitive Processes

Leon Reicherts
UCL Interaction Centre
University College London
London, United Kingdom
l.reicherts.17@ucl.ac.uk

Yvonne Rogers
UCL Interaction Centre
University College London
London, United Kingdom
y.rogers@ucl.ac.uk

ABSTRACT

Traditionally, a key concern of HCI has been to design interfaces that should not make the user think. While this is – and will continue to be – desirable for most systems, there are also situations in which a system that prompts and questions the user may be more appropriate. In educational systems for instance, tasks are often intentionally made more challenging to enable "deeper" thinking and more thorough learning. Although conversational interfaces are still relatively limited in their capabilities, they seem very promising for contexts where questioning is needed, such as learning, analytics or sensemaking as well as safety-critical systems. Overly simple interactions – such as when the user can just *tap* or *drag and drop* – may not be beneficial in this context or may even be risky. In this position paper, we discuss previous work as well as opportunities where questioning users through conversation can be beneficial, based on insights from our own research.

CCS CONCEPTS

• Human-centered computing~Human computer interaction (HCI)~Interaction paradigms~Natural language interfaces

KEYWORDS

Conversational user interfaces; cognition; slow interaction; prompting; questioning; problem solving; sensemaking; analytics; data exploration.

ACM Reference format:

Leon Reicherts and Yvonne Rogers. 2020. Do Make me Think! How CUIs Can Support Cognitive Processes. In *Proceedings of the International Conference on Conversational User Interfaces (CUI 2020). ACM, New York, NY, USA, 4 pages.* https://doi.org/10.1145/1234567890

CUI 2020, July 2020, Bilbao, Spain

1 Introduction

Traditionally, the focus of HCI and usability has been on making interactions as easy as possible. The user should not even have to think (e.g. the book title *Don't make me think* by Steve Krug [9]). Indeed, it is desirable for most tools, devices and applications to be as easy to use as possible. However, here we argue that this can be different depending on what the user is trying to achieve at the interface, such as improving their activities of sensemaking, problem-solving and learning – or performing a safety-critical task. In such situations, prompting and questioning at appropriate/opportune points in the interaction may lead to more meaningful outcomes. Although such prompts may sometimes be annoying, they can also help users think about certain actions, choices or conclusions.

An example of an "easy-to-click" interface is *Tableau* [19]. The program makes it simple for the user to filter and visualize complex datasets. It enables lay users to conduct analyses, which only data analysts could do a couple of years ago. With just a few clicks, it allows users to generate almost any type of visualization that is "generatable" based on the type of data in a specific dataset. However, choosing an appropriate visualization and understanding it generally requires certain methodological and domain-related knowledge. It is often the case that the easier an interface, the less users need to think about their actions. While it may be appropriate to make a task less cognitively demanding in many cases, there are also situations where the opposite is true. For example, how does a lay user know whether a *treemap* or a *stacked bar chart* is the more appropriate visualization of a specific dataset? Asking users certain questions about what they are hoping to discover at the interface may help them in their decision.

Natural language interfaces or Conversational User Interfaces (CUIs) offer great potential in situations like the one described above, since they can prompt, guide and scaffold users' thinking when doing a task. More generally, conversational interaction seems suitable for tasks that are new to the user, ill-structured, open-ended or exploratory. In such scenarios, users may not know what they are looking for or what they

need to do, and a conversational agent can help them to keep on track.

Graphical User Interfaces (GUIs), on the other hand, are ideally suited for direct manipulation (e.g. filtering, selecting, zooming and scanning). When users know what they are looking for or if they are doing a familiar task, GUIs may be most suitable. Of course, GUIs and CUIs are not mutually exclusive, particularly when thinking of a chatbot, which may be integrated into an application's GUI. For example, users can interact with the *Amazon Echo Show* [20] through voice as well as through a touchscreen interface. Furthermore, users can be verbally or textually prompted within a GUI through pop-up windows, for example.

The goal of this position paper is not to argue about the benefits of CUIs over GUIs, but to consider the potential of CUIs in being able to scaffold users' thinking when simple GUI prompts, such as pop-ups, may not be sufficient or appropriate. Exploring further in which types of activities CUIs can successfully support users' cognitive processes will help to inform design choices as to where a CUI may be more effective than a GUI – as well as where they could complement each other.

2 Background

2.1 Cognitive Scaffolding Through Questions

Having an interface, which can guide and facilitate users' thinking and reasoning through conversational interactions, such as by asking questions or providing suggestions, may be highly desirable in certain situations. In the context of learning and education, for example, questioning and problematizing is used by tutors/teachers to guide students towards (scientific) sensemaking [2] or to scaffold their problem solving [8,11]. Questions are a crucial element of scientific thinking and intellectual exploration [16], for instance in the case of exploratory data analysis [15].

Hence, an interface that probes and guides users through suggestions and questions might play a central role in many cognitive tasks, in particular, if they are ill-structured or open-ended. This could be relevant not only in the context of learning and data exploration but also with regards to problem-solving, decision-making and even safety-critical tasks. Previous research suggests that CUIs seem particularly suitable to guide and scaffold thinking, which we will describe in the next section.

2.2 Scaffolding Users' Thinking with CUIs

A benefit of using conversational agents at the interface is that they can provide suggestions to the user concerning what to do next or what else to consider. For example, Winkler et al. [18] showed that an Alexa-based tutor can have a positive effect on the task outcome and collaboration among users in a problem-solving task. In another project, Winkler and colleagues [17] showed that a conversational agent, which scaffolded learners understanding in the context of online courses, has more positive effects on learning compared to an agent that did not scaffold. Similarly, Song et al. [13] developed a conversational agent that was successful at getting learners to think about their progress by asking them questions. Moreover, Tegos et al. [14] demonstrated that conversational agents which intervene in students' conversations by asking open-ended learning questions can substantially improve both individual and group learning outcomes. Taken together, this line of research shows the value of conversational assistants that scaffold thinking, learning and problem-solving.

2.3 CUIs in Analytics Tools

While analytics tools have begun to incorporate CUIs to make it easier for users to query data or express their data-related questions [5,6,12] another line of research is to consider how they can be designed to guide and scaffold users' problem solving. For instance, *Iris* by Fast et al. [3] provides a chatbot interface which supports data scientists in open-ended modelling tasks – the "structural guidance" provided by *Iris* was found to be particularly useful in their user study. Another example is *Ava* by John et al. [7], which allows data scientists to assemble data analytics pipelines, using a chatbot interface. Overall, this research suggests the use of CUIs can both help users express their data-related questions and provide scaffolds and guidance for complex analytics tasks.

3 Our Approach

To further investigate the potential of CUIs, which prompt users and scaffold their thinking, we have developed an interface prototype for a data analytics set-up. An "assistant" was designed to be part of a data analytics system which asks users questions about the data being visualized. The questions aim to draw the users' attention to differences and trends within the dataset, which should help them think about the data more thoroughly and to articulate hypotheses about why there are certain patterns. The chosen visualizations were time series graphs on increasing obesity levels in different countries from 1990-2013. They were based on Marinez [10] and the underlying dataset was from the Global Burden of Disease Study [4]. These visualizations were chosen, as they were simple enough to understand, but also as they contain relatively nuanced differences that need to be teased out (e.g. subtle changes in growth rates), which often require more detailed analysis.

A study was conducted in which participant pairs were asked to look at the visualizations and to discuss and hypothesize about patterns they saw in the data. There were two reasons

for choosing pairs instead of single users. First, in a single user scenario, it can feel unnatural for someone to speak to a system. Second and most importantly, running the study in pairs provides opportunities to examine the kinds of conversations that would take place (also see [1]). Furthermore, talking to each other about the data can trigger further reasoning and thinking about the data.

The aim of the study was to examine the sensemaking, which occurs, when the pairs are prompted by the interface. The prompts, which were provided through the assistant, were aimed at stimulating the participants' discussion. A *Wizard of Oz* experiment was conducted; the prompts were controlled by a human, who pretended to be the assistant. Participants were told that they could, but did not have to, respond to the assistant's suggestions. The assistant was designed to ask a number of predefined questions, such as "*Would you say that the increase is slowing down for all four groups?"* or *"Have we seen this pattern elsewhere?"* or *"For whom would you say was the increase more steady throughout time?"*. There were two rules for triggering a question: (a) there was silence in the conversation for at least three seconds, and (b) participants have not previously discussed a topic directly related to that question. After the participants had explored the dataset, they were asked about their experience of interacting with the system and the assistant in a semi-structured interview. In the following section, we provide an overview of some of our key insights from these interviews.

4 Insights from the User Study

Overall, most participants found the assistant's prompts particularly useful for making them think about the given dataset from different perspectives. For example:

> [Participant 1 - Pair 5] *"It would tell us to think about stuff we didn't see at first, but they were really interesting to think about."*

Several pairs found that the assistant made them do the analysis task more slowly than if they had done the task without it. Many participants also found that this "slowing down effect" had benefits, for example, in situations where users are trying to better understand a certain topic/dataset to get a new perspective:

> [P1-P18] *"I think it is good [to use this system] if you have time and you are trying to figure out things."*

> [P2-P11] *"I mean it was more time-consuming than traditional tools but that also has benefits if you are not in a rush."*

Some individuals also mentioned that when users become more familiar with the dataset, they may prefer the system to become faster:

> [P1-P6] *"If you are looking at the same data for an extended period of time, you mostly want it to be very fast to get data out. This isn't exactly fast. I guess this is more suitable if you are introducing a new topic or you are trying to get a new perspective on the same data."*

Similarly, many participants mentioned that they would rather not use the system when doing a familiar task and knowing what to look for:

> [P1-P8] *"If you have a lot of variables and you are not really sure what you are looking for or if you are training someone it might be a good thing to use. If I know what I am looking for, I probably won't use it. (…) I would use it to generate hypotheses instead of testing my hypotheses."*

However, several participants pointed out that the assistant helped them to not get lost or stuck on a particular data visualization. Furthermore, it allowed them to find additional differences or trends in the data when they thought that they had already discovered everything, for example:

> [P2-P7] *"For complex datasets this would be very useful, because when there are so many parameters (…) you might get lost in the data – like where you have started and where you are ending it (…) It could give me a starting point when I am confused."*

> [P1-P8] *"I think one thing that helped was that when we were kind of stuck and we were not saying anything, it would just generate a suggestion. I found that useful."*

> [P2-P10] *"I like the fact the questions were about finding more in the data. By looking at the question, you would think about the question and you would think about why (…) this is more steady than the other, which wouldn't happen without the assistant."*

A few participants also found that discussing the data in the context of the assistant's questions helped them to better remember certain aspects of the data:

> [P1-P18] *"I am really impressed by what we all remember from that, so maybe it is also a good thing for remembering data by talking about it and having some kind of facilitator."*

Overall, the system and its assistant were perceived as helpful for the exploratory, open-ended task participants were asked to carry out. Prompting via questions, which were aimed to help them to discover (nuanced) differences, was also found to be useful in most cases. Furthermore, participants found that the prompts had a stimulating effect on their discussion. The fact that the system sometimes slowed users down was generally perceived as beneficial for this type of task. However, in line with our expectations, participants commented that it might not be desirable to be slowed down when completing a familiar task or topic, where users know

what they are looking for – unless they would like to approach it from a new angle. These comments highlight the trade-off between "speed and scaffolding", where one enables the user to get their task done efficiently and the other can lead to deeper thinking.

Conclusion

Findings from our preliminary research suggest that questioning user actions through conversational interfaces has great potential, especially in settings where other types of interfaces may not be able to scaffold users thinking and provide sufficient guidance. However, the effect of "slowing down" someone's thinking in this way can increase the cognitive effort required. This may be appropriate for certain types of tasks and settings but not for others.

ACKNOWLEDGMENTS

This work was partially funded by the *U Bremen Excellence Chairs program*.

REFERENCES

[1] Richard Arias-Hernandez, Linda T. Kaastra, Tera M. Green, and Brian Fisher. 2011. Pair Analytics: Capturing Reasoning Processes in Collaborative Visual Analytics. In *2011 44th Hawaii International Conference on System Sciences*, 1–10. DOI:https://doi.org/10.1109/HICSS.2011.339

[2] Amanda Benedict-Chambers, Sylvie M. Kademian, Elizabeth A. Davis, and Annemarie Sullivan Palincsar. 2017. Guiding students towards sensemaking: teacher questions focused on integrating scientific practices with science content. *International Journal of Science Education* 39, 15 (2017), 1977–2001. DOI:https://doi.org/10.1080/09500693.2017.1366674

[3] Ethan Fast, Binbin Chen, Julia Mendelsohn, Jonathan Bassen, and Michael S. Bernstein. 2018. Iris: A Conversational Agent for Complex Tasks. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems - CHI '18*, ACM Press, Montreal QC, Canada, 1–12. DOI:https://doi.org/10.1145/3173574.3174047

[4] Global Burden of Disease Collaborative Network. 2014. *Global Burden of Disease Study 2013 (GBD 2013) Obesity Prevalence 1990-2013.* Institute for Health Metrics and Evaluation (IHME), Seattle. Retrieved from http://ghdx.healthdata.org/record/global-burden-disease-study-2013-gbd-2013-obesity-prevalence-1990-2013

[5] Lars Grammel, Melanie Tory, and Margaret-Anne Storey. 2010. How information visualization novices construct visualizations. *IEEE Transactions on Visualization and Computer Graphics* 16, 6 (December 2010), 943–952. DOI:https://doi.org/10.1109/TVCG.2010.164

[6] E. Hoque, V. Setlur, M. Tory, and I. Dykeman. 2018. Applying Pragmatics Principles for Interaction with Visual Analytics. *IEEE Transactions on Visualization and Computer Graphics* 24, 1 (January 2018), 309–318. DOI:https://doi.org/10.1109/TVCG.2017.2744684

[7] Rogers Jeffrey Leo John, Navneet Potti, and Jignesh M. Patel. 2017. Ava: From Data to Insights Through Conversations. In *CIDR 2017*.

[8] Minchi C. Kim and Michael J. Hannafin. 2011. Scaffolding problem solving in technology-enhanced learning environments (TELEs): Bridging research and theory with practice. *Computers & Education* 56, 2 (February 2011), 403–417. DOI:https://doi.org/10.1016/j.compedu.2010.08.024

[9] Steve Krug. 2005. *Don't Make Me Think: A Common Sense Approach to the Web (2nd Edition)*. New Riders Publishing, USA.

[10] Ramon Marinez. 2015. Level and Trends of Overweight and Obesity. *Tableau Public*. Retrieved September 17, 2019 from https://public.tableau.com/profile/ramon.martinez#!/vizhome/LevelandTrendsofOverweightandObesity/Overweightandobesitylevel

[11] Brian J. Reiser. 2004. Scaffolding Complex Learning: The Mechanisms of Structuring and Problematizing Student Work. *Journal of the Learning Sciences* 13, 3 (2004), 273–304. DOI:https://doi.org/10.1207/s15327809jls1303_2

[12] Vidya Setlur, Sarah E. Battersby, Melanie Tory, Rich Gossweiler, and Angel X. Chang. 2016. Eviza: A Natural Language Interface for Visual Analysis. In *Proceedings of the 29th Annual Symposium on User Interface Software and Technology* (UIST '16), ACM, New York, NY, USA, 365–377. DOI:https://doi.org/10.1145/2984511.2984588

[13] Donggil Song, Eun Young Oh, and Marilyn Rice. 2017. Interacting with a conversational agent system for educational purposes in online courses. In *2017 10th International Conference on Human System Interactions (HSI)*, 78–82. DOI:https://doi.org/10.1109/HSI.2017.8005002

[14] Stergios Tegos and Stavros N. Demetriadis. 2017. Conversational Agents Improve Peer Learning through Building on Prior Knowledge. *Educational Technology & Society* 20, (2017), 99–111.

[15] John W. Tukey. 1980. We Need Both Exploratory and Confirmatory. *The American Statistician* 34, 1 (1980), 23–25. DOI:https://doi.org/10.2307/2682991

[16] Ronald D. Vale. 2013. The value of asking questions. *Mol Biol Cell* 24, 6 (March 2013), 680–682. DOI:https://doi.org/10.1091/mbc.E12-09-0660

[17] Rainer Winkler, Sebastian Hobert, Antti Salovaara, Matthias Söllner, and Jan Marco Leimeister. 2020. Sara, the Lecturer: Improving Learning in Online Education with a Scaffolding-Based Conversational Agent. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems* (CHI '20), Association for Computing Machinery, Honolulu, HI, USA, 1–14. DOI:https://doi.org/10.1145/3313831.3376781

[18] Rainer Winkler, Matthias Söllner, Maya Lisa Neuweiler, Flavia Conti Rossini, and Jan Marco Leimeister. 2019. Alexa, Can You Help Us Solve This Problem?: How Conversations With Smart Personal Assistant Tutors Increase Task Group Outcomes. In *Extended Abstracts of the 2019 CHI Conference on Human Factors in Computing Systems - CHI EA '19*, ACM Press, Glasgow, Scotland Uk, 1–6. DOI:https://doi.org/10.1145/3290607.3313090

[19] Tableau: Business intelligence and analytics software. *Tableau Software*. Retrieved February 9, 2020 from https://www.tableau.com/en-gb

[20] Echo Show 2nd Generation. Retrieved September 20, 2019 from https://www.amazon.co.uk/Amazon-Echo-Show-With-Screen-2nd-Generation-Alexa/dp/B0793G9T6T