Eurographics Conference on Visualization (EuroVis) (2012)
M. Meyer and T. Weinkauf (Editors)

The Effects of Visualization Feedback on Promoting Health Goal Progress in Older Adults

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Abstract

Working towards and maintaining goals is closely tied to healthy aging, but aging researchers know little about how older adults work towards their meaningful goals on a daily basis. We conducted an internet-based micro-longitudinal study (100 days, n=105) to examine factors that may affect older adults' abilities to self-regulate health goals over time with a focus on the role of visualization feedback on promoting their progress. Our findings suggest that (1) older adults found visualization feedback helpful in maintaining an awareness of their health goal progress, and (2) visualization feedback weakens the positive relationship between the previous day's progress and today's progress, helping older adults bounce back from a poor progress day.

Categories and Subject Descriptors (according to ACM CCS): H5.m. [Information interfaces and presentation (e.g., HCI)]: Miscellaneous—

1. Introduction

Advancements in computing technology and increasing internet use, especially among older adults [WHH10], have opened new opportunities for researchers to study people's lives via online experiments. In the domain of aging sciences, researchers are interested in using online and mobile technologies to study older adults' daily processes of managing health and well-being [MPH*08]. Researchers aim to identify age-related risk factors, and provide tools to help older adults maintain a healthy lifestyle.

Beyond awareness of health risk factors, healthy aging requires individuals to also maintain healthy behaviors across their lifespan. Thus, to support their identities and life goals, individuals must develop and use self-regulatory skills and strategies [HM03]. Self-regulation is a well-known model of human functioning in which behaviors are seen as goal-directed and regulated by feedback control processes [CS01]. People will strive to close gaps between their current status and their goals if provided with appropriate feedback. All models of motivation and behavior (e.g., [CS01, LL90]) emphasize the importance of *feedback processes*. Therefore, an important task for aging researchers is to create and test methods to track and deliver personalized information about one's own health indicators.

The Personal Understanding of Life and Social Experiences (PULSE) project was an internet-based study that examined intraindividual variation in daily progress toward goals. The study targeted younger older adults whose age is over 50 because healthy behaviors at this time of life are linked to positive health outcomes in older adulthood [HS04]. Furthermore, this population is increasingly interested in using technology to maintain or improve their health [WHH10]. We designed a web-based application that allowed participants to log their daily goal progress, provided access to visualization of their data, and served as a survey management tool for the researchers. **In this paper, our emphasis is on the role of visualization feedback and its effects on promoting progress toward health-related goals in younger older adults.** To our knowledge, PULSE was the first microlongitudinal study with a large sample of older adults (100 days, $n = 105$) to be implemented in its entirety via the web.

2. Related Work

The HCI and InfoVis communities have shown considerable interest in methods for collecting data online and using visualization feedback for purposes of behavior change [CLM09, FDK*09, LD11, HGH10], compliance [HLD*08], and simply to develop self-knowledge [LDF10, KG10].

Li and colleagues [LDF10] proposed a five-stage model of personal informatics systems, two of which were reflection and action. In this paper, we focus on the use of visualization feedback to motivate self-reflection and action.

On the use of visualization as feedback, Hsieh and col-

DOI: 10.2312/PE/EuroVisShort/EuroVisShort2012/091-095

leagues [HLD*08] found from their experience sampling (ESM) study that providing visualization feedback to participants resulted in an increase of 23% in the compliance rate. In this paper, our focus is not on compliance but on the effects of visualization feedback on goal progress.

3. The PULSE Study

Protocol and Participants. The PULSE project was an internet-based 100-day study of Oregon (USA) residents over the age of 50. Out of 105 initial participants (mean age of 63.13, 88% female, 97% white), 99 completed the study. The study was designed to examine psychosocial, health, and feedback factors that may affect adults' abilities to self-regulate health and social goals over time. Findings in this paper emphasize feedback factors and health goals.

The study consisted of two main phases: (1) An initial one-hour (approximate) survey that included measures of participants' health, personality, goals, and social networks; and (2) a daily survey (designed to be completed in five minutes) of progress towards goals and factors that helped or hindered goal progress over a 100-day period. Goals and social contacts provided in the initial survey populated the participants' daily surveys. Each daily survey was followed by visualization feedback of daily responses. On the last day of participation, participants received a one-page questionnaire about their study experience and the visualization feedback. Participants chose their goals, which we reviewed and communicated with participants to ensure that they were measurable and meaningful for keeping track of on a daily basis.

The PULSE application. The PULSE application was designed to serve as a personal informatics system for participants [LDF10] and a survey management tool for the researchers. For researchers, the application supported management of survey questions, participants, and daily questionnaires. For participants, the application allowed them to log their daily goal progress and to access a visual representation of their data.

Figure 1 shows an example daily survey question for health goal progress (refer to the supplemental document for screenshots of a complete daily survey). In this paper, we are interested in the potential relationships between responses to this question and the use of visualization feedback.

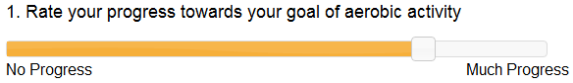

Figure 1: *Example of health goal progress question in the daily survey of a participant. Responses for this question are based on a continuous sliding scale from 0 (No Progress) to 100 (Much Progress).*

Visualization Feedback. After completing a daily survey, participants were redirected to their visualization feedback page. This page presented visualizations of participants' goal progress as well as other facets of their daily

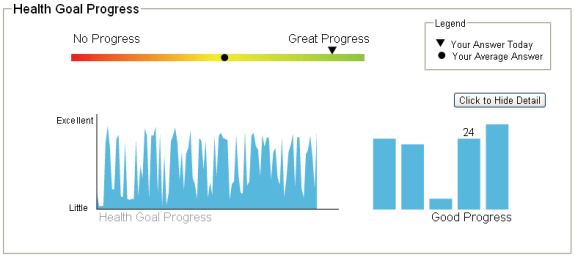

Figure 2: *Visualizations as feedback on health goal progress of a participant on a particular day of the study. Participants may show/hide the detailed time-based area chart and histogram charts.*

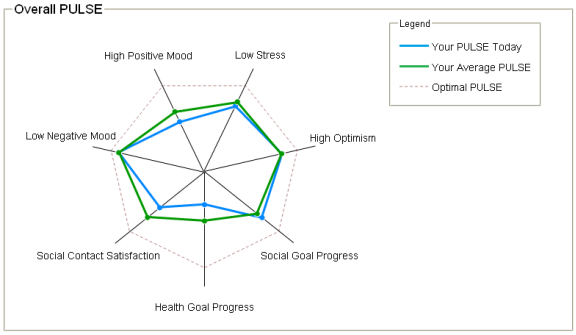

Figure 3: *Star plot visualization of multiple facets for a participant on a particular day of the study.*

lives, which were derived from aggregated daily survey answers of optimism, stress, mood, and social satisfaction.

We intended to choose standard 2D visualizations, as classified by Keim [Kei02], that are familiar to users. In particular, each facet was presented with a horizontal meter displaying the current day's response and how it compared to the average response for that participant up to that day in the study. In addition, each facet had a 'Detail' button to show (or hide) two additional detailed visualizations (see Figure 2). On the left, a time series area chart showed how responses changed over the time span of the study and on the right, histograms showed how responses were distributed across pre-defined categories. Participants could mouse over these charts to see additional labels and data tips. In this paper, we are particularly interested in participant interactions with visualizations of health goal progress (see Figure 2).

The visualization feedback page also offered a star plot visualization that gave participants an overview of their responses across multiple facets relative to their average responses and optimal responses (see Figure 3).

Visualizations were implemented with the Protovis Visualization Toolkit (http://vis.stanford.edu/protovis/) and the Raphaël JavaScript Toolkit (http://raphaeljs.com). They were tested on most of the common browsers.

Logging of Time and User Interactions. We monitored

the use of the visualization page in terms of time spent and number of interactions. Specifically, the application was instrumented to record start and end time when participants opened and closed pages. These data were used to compute the time (in seconds) participants spent every day on their visualization page. The application also recorded clicks when participants showed or hid the detailed visualizations.

4. Analysis and Results

4.1. Does visualization affect health goal progress?

To understand the causal effect of visualization use (i.e., time spent on or clicking on the visualizations) on health goal progress, in our analysis, we broke down the above question into three subquestions:

(SQ1) What is the association between today's goal progress and today's use of visualization feedback? (Note that participants viewed and interacted with visualization feedback *after* completing their daily surveys.)

(SQ2) Is below-average goal progress yesterday related to today's goal progress (the lag-effect)?

(SQ3) Is the lag-effect of poor goal progress yesterday attenuated when participants use their visualization feedback?

To test these hypotheses, we performed time-lag analyses on daily survey data using a multilevel regression model where repeated daily surveys were nested within persons.

For **(SQ1)**, multilevel regression revealed convincing evidence that on days participants reported low progress, they were more likely to spend more time than their average on the visualization page ($slope(b) = -0.0006, p = 0.05$) and were also more likely to click on the health goal visualization for further details ($b = -3.1, p = 0.03$).

For **(SQ2)** and **(SQ3)**, we ran tests in which today's goal progress is a function of both yesterday's progress being above or below average and yesterday's use of the visualization as well as interaction between these two covariates. In other words, these tests accounted for the effect of being above or below average yesterday on today's goal progress, and specified the degree to which using visualization changes (moderates) this association.

The results show that below (or above) average goal progress yesterday has a negative (or positive) effect on today's progress ($b = .2, p = 0$). Simply put, below average progress yesterday carries over to today's progress. However, the significant interaction term suggests that spending time (in seconds) viewing the visualization yesterday dampens that effect ($b = -.0003, p = .05$) (see Figure 4). This moderation effect was not evident in clicking on the health goal visualization for further details.

In summary, although the effect sizes appear small, results suggest that some participants may have used the visualization in response to making low progress toward their health goals. More importantly, spending time viewing the visualization helps participants bounce back after doing poorly yesterday. Perhaps the visualization allowed participants an opportunity to reflect on their goals, and resolve to do slightly better the following day.

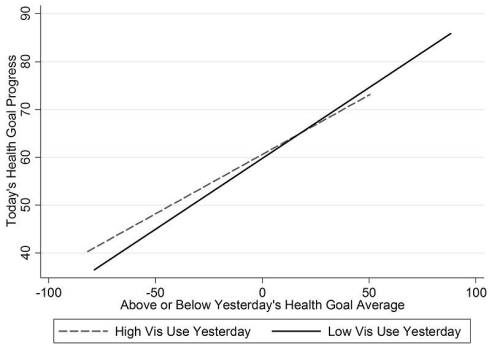

Figure 4: *Yesterday's spending time on visualization (High Vis Use Yesterday) slightly attenuates the relationship between yesterday's and today's health goal progress*

Question	Mean (SD)
Q1: I liked the visualizations.	65.66 (24.52)
Q2: I found the visualizations useful.	61.26 (27.71)
Q3: The visualizations helped me maintain an awareness of my daily social/health goals and habits.	60.76 (28.51)
Q4: I found the visualizations confusing	27.79 (26.21)

Table 1: *Mean responses to each of four sliding scale questions in the post study questionnaire. These responses are based on a scale from 0 (Strongly Disagree) to 100 (Strongly Agree). Standard deviations are shown in parentheses.*

4.2. Subjective Evaluation

On the last day of the study, participants received a one-page questionnaire requesting their thoughts on the study and on the visualization feedback. We analyze responses to seven visualization-related questions here.

Table 1 lists the four sliding scale questions along with the participants' mean responses. Overall, participants moderately favored visualization as a useful tool to help maintain an awareness of their goal progress. Interestingly, linear regression also revealed that participants who found the visualization useful (Q2) and helpful for their awareness (Q3) tended to report higher mean progress towards health goals (Q2: $b = 0.38, p = 0.01$; Q3: $b = 0.38, p = 0.01$).

In addition to the sliding scale questions, the questionnaires included the following three open-ended questions: (Q5) What aspect(s) of the visualizations did you like most? (Q6) What aspect(s) of the visualizations did you dislike most? (Q7) Is there anything that you would like to know that you couldn't determine from the visualizations?

Many participants liked the meter visualization for its

ability to compare daily responses with average responses. *"The spectrum provided a scale for making judgments. As the days progressed, I realized that though there was some fluctuation in the results, the overall results were consistent. This was reassuring."* (P91)

Many also appreciated multiple facets of the star plot visualization. Several participants praised the time series chart for its ability to support self-reflection over time. *"Seeing the spikes up or down made me reflect on what was so bad or good and how could I see things differently or what could I do to improve my mood or confidence. The circle summary at the end was helpful - it would be interesting to be able to see how it looked at the end of each week too. I liked that it showed if it was a good day or bad day."* (P149)

However, participants also pointed out several issues with the visualization feedback, which are barriers to self-reflection as discussed in [LDF10].

Interpretation of visualization. Several participants asked for more description and explanation on the charts, especially on the histograms. In addition, ten participants mentioned they were not familiar with the word "visualization" that we used in the post-study questionnaire.

No context. Several participants pointed out the lack of contextual information in the visualization feedback. *"It would be great to be able to click on a date in a chart and be able to go to the journaling for that day and see why there was a spike. It would allow for reflection on how things may not have been so bad or would show that things have improved."* (P149)

Data are not useful. Some participants found that visualizations were not useful for them because they knew what they were doing already. *"I briefly glanced at the charts. I knew when I had a good day and didn't really need the charts."* (P76)

4.3. Other Results

The compliance rate, computed as the mean percentage of daily surveys completed among participants, is 84.26%. We suspect that visualizations, which provide feedback and keep participants engaged on a daily basis, may contribute to this extremely high rate. We suspect that visualization literacy in our sample is relatively high because only a small portion of participants (27.79%) found the visualization confusing in the subjective evaluation and our sample is relatively educated, with 77.14% earning a bachelor's degree or higher.

5. Discussion and Future Work

We have presented our findings on how visualization feedback may affect progress toward health-related goals in a large sample of younger older adults over an extended time period. Like most studies, ours has limitations, which we discuss here and suggest directions for future work.

Study Issues. First, with respect to studying the role of visualization feedback on promoting goal progress, PULSE is an observational study that does not necessarily require a control group. Nevertheless, in the future work, it would be informative to conduct controlled studies that compare visualization with non-visualization feedback, examine different types of visualizations, or customize visualization feedback for different types of goals.

Second, our mechanism of logging time had limitations. End time was not recorded accurately if participants did not close the visualization page after viewing it. For our analyses, we adjusted durations of these invalid end times. In particular, an invalid duration from a participant was adjusted to the average duration of all valid durations of that participant. For future studies, a timer on pages that triggers confirmation dialog after an interval of not receiving user interactions would improve this mechanism.

Usability Issues. First, the number of user interactions (i.e., clicking to show more detail) with the visualization is low. As mentioned earlier, participants could interact and benefit more from the visualization feedback if the application interface provided more helpful instructions, explanation, and contextual information. Possible directions for future work include the investigation of engaging or emotionally motivational designs [HGH10] that for example, allow users to personalize the interface according to their goals and annotate their progress on the visualizations.

Second, since the sliders in the surveys were presented with their handles by default in the middle, these anchoring values may potentially cause bias in the responses [BK03]. An improved slider design might, for example, hide its handle initially and only show it after getting a mouse click from users. The concept is similar to using radio buttons without an initial choice [BK03].

Social goals. Beside health-related goals, participants in our study also self-regulated progress towards their social-related goals. Nevertheless, the results are not as clear for social domain and explanation may require a more direct engagement with participants about the relationships between visualization use and goal progress. We reserve deeper investigation of this matter for future work.

6. Conclusion

In this paper, our primary finding suggests that using the visualization yesterday weakens the lag effect between yesterday's and today's goal progress. To aging researchers, this finding re-emphasizes the importance of feedback processes in the self-regulation model. To visualization researchers, this finding suggests the need for deeper investigation into visualization as a promising method to track and deliver personalized information in applications targeting older adults.

Acknowledgments

We would like to thank our study participants for their time and input. The PULSE Project is sponsored by Oregon State University's Center for Healthy Aging Research.

References

[BK03] BURKEY J., KUECHLER W.: Web-based surveys for corporate information gathering: a bias-reducing design framework. *Professional Communication, IEEE Transactions on 46*, 2 (2003), 81–93. 4

[CLM09] CONSOLVO S., LANDAY J., MCDONALD D.: Designing for behavior change in everyday life. *Computer 42*, 6 (2009), 86–89. 1

[CS01] CARVER C., SCHEIER M.: *On the self-regulation of behavior*. Cambridge University Press, 2001. 1

[FDK*09] FROEHLICH J., DILLAHUNT T., KLASNJA P., MANKOFF J., CONSOLVO S., HARRISON B., LANDAY J.: Ubigreen: investigating a mobile tool for tracking and supporting green transportation habits. In *Proceedings of the 27th international conference on Human factors in computing systems* (2009), ACM, pp. 1043–1052. 1

[HGH10] HE H., GREENBERG S., HUANG E.: One size does not fit all: applying the transtheoretical model to energy feedback technology design. In *Proceedings of the 28th international conference on Human factors in computing systems* (2010), ACM, pp. 927–936. 1, 4

[HLD*08] HSIEH G., LI I., DEY A., FORLIZZI J., HUDSON S.: Using visualizations to increase compliance in experience sampling. In *Proceedings of the 10th international conference on Ubiquitous computing* (2008), ACM, pp. 164–167. 1, 2

[HM03] HOOKER K., MCADAMS D.: Personality reconsidered: A new agenda for aging research. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences 58*, 6 (2003), P296. 1

[HS04] HOLAHAN C., SUZUKI R.: Adulthood predictors of health promoting behavior in later aging. *The International Journal of Aging and Human Development 58*, 4 (2004), 289–313. 1

[Kei02] KEIM D.: Information visualization and visual data mining. *Visualization and Computer Graphics, IEEE Transactions on 8*, 1 (2002), 1–8. 2

[KG10] KILLINGSWORTH M., GILBERT D.: A wandering mind is an unhappy mind. *Science 330*, 6006 (2010), 932. 1

[LD11] LEE M., DEY A.: Reflecting on pills and phone use: supporting awareness of functional abilities for older adults. In *Proceedings of the 2011 annual conference on Human factors in computing systems* (2011), ACM, pp. 2095–2104. 1

[LDF10] LI I., DEY A., FORLIZZI J.: A stage-based model of personal informatics systems. In *Proceedings of the 28th international conference on Human factors in computing systems* (2010), ACM, pp. 557–566. 1, 2, 4

[LL90] LOCKE E., LATHAM G.: *A theory of goal setting & task performance.* Prentice-Hall, Inc, 1990. 1

[MPH*08] MATTILA E., PARKKA J., HERMERSDORF M., KAASINEN J., VAINIO J., SAMPOSALO K., MERILAHTI J., KOLARI J., KULJU M., LAPPALAINEN R., ET AL.: Mobile diary for wellness management—results on usage and usability in two user studies. *Information Technology in Biomedicine, IEEE Transactions on 12*, 4 (2008), 501–512. 1

[WHH10] WAGNER N., HASSANEIN K., HEAD M.: Computer use by older adults: A multi-disciplinary review. *Computers in Human Behavior 26*, 5 (2010), 870–882. 1