The impact of specificity in visualizing study behaviour

Willem Nijmeijer

Utrecht University

Student number: 6310311

First assessor: C. Hulshof

Second assessor: J. Jaspers

Word count: 4098

THE IMPACT OF SPECIFICITY IN VISUALIZING STUDY BEHAVIOUR

Abstract

This paper investigates to what extent specificity of information in a visualization has a regulatory effect on a person's behaviour. The visualizations in this study display a person's own perception of their study behaviour. The hypothesis is that the degree of specificity of information in a visualization has a regulatory effect on a person's general perception of the visualization. During this research, 3 experimental conditions were set up, in which students were shown a visualization with the same information, but the level of specificity of information differed. The visualization with the lowest level of information only showed the main constructs of study behaviour, the visualization with the medium level of information also showed the subconstructs of study behaviour and the visualization with the highest level of information also showed a description of the subconstructs. The data was collected by means of a questionnaire. The results of the study show that visualizations with minimal specificity are generally perceived less useful than visualizations with medium to high specificity of information. The conclusion is therefore to provide visualizations about study behavior with at least sub-constructs.

**Keywords:** *Visualization, specificity of information, study behaviour*

In the past decade, an enormous number of tools and applications have been created that enable people to collect personal data (Alrehiely, 2020; Choe et al., 2017). Most insights and actions are based on information collected from various sources (Somervell et al., 2002). A shared characteristic in many of these tools is that they make intensive use of informative visualizations in order to show the performance of the user. Visualizations quickly and effectively provide access to information to users. (Li et al., 2010; Lin et al., 2006; Kersten-van Dijk et al., 2017). Personal information about health, exercise and wellbeing supports informal learning and behavioural change (Kersten-van Dijk et al., 2017).

Visualization methods are not one-size-fits-all. It is known that humans have the ability to hold a limited number of chunks of information at any given time (Sanjinis, 2018). Although the amount of data written in a visualization is not fixed, the presence of an accompanying text with a visualization ensures that the information is better remembered and preserved. (Larkin & Simon, 1987; Kostromina & Gnedykh, 2015). Direct labelling information in a visualization reduces the cognitive load on the user's working memory and allows for more efficient mental processing (Mayer, 2008; Evergreen & Metzner, 2013).

Including a lot of data in a visualization puts more strain on working memory than any benefit they can provide (Sweller, 1988). To reduce the risk of overload, the designer often processes parts of the information. The result is that users "skip" some mental steps that they should have made when reading a normal text. The designer of a visualization creates 'pre-chunks', essentially storing more information in working memory than would otherwise be possible. According to Evergreen and Metzner (2013), simplifying a visualization makes it easier to process. For example, when a visual is rich in information it makes the visual difficult to process (see Figure 1). In contrast, the design of Figure 2 has a simpler display with smaller chunks of information which make the visual easier to process.
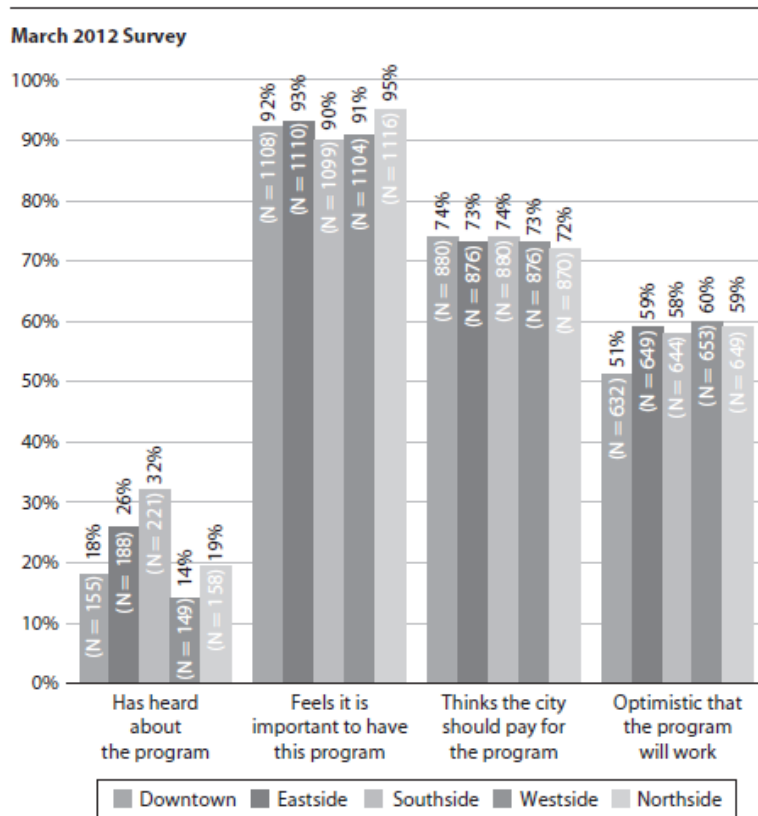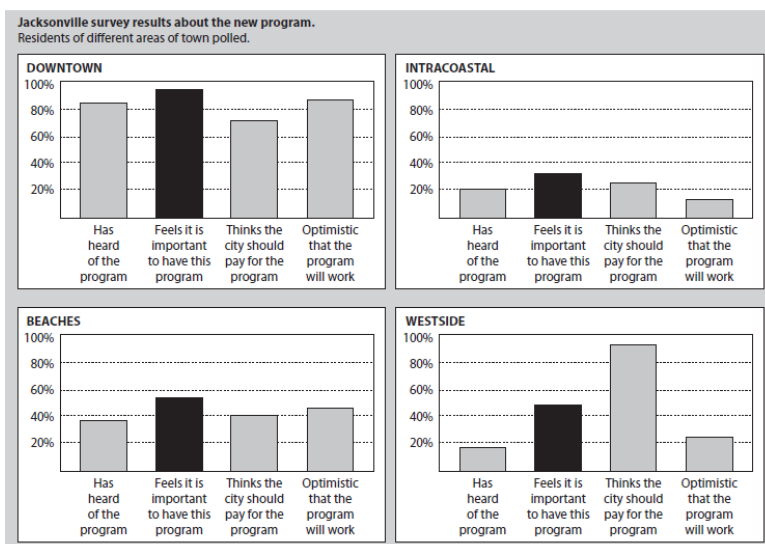
Figure 1

Note. Adapted from Evergreen, S., & Metzner, C. (2013). Design principles for data visualization in evaluation. *New directions for evaluation*, *2013*(140), p. 9

Figure 2

Note. Adapted from Evergreen, S., & Metzner, C. (2013). Design principles for data visualization in evaluation. *New directions for evaluation*, *2013*(140), p. 10

Although research has been done on visualizations, it is also a relatively new field of research. In addition, the design of a visualization depends on the target group and the goal that the designer wants to achieve (Kersten-van Dijk et al., 2017). The current study was done in the context of education and well-being. This study investigates how much data is desirable in a visualization of study behaviour to generate more awareness and adjustment of behaviour.

Learning analytics

Arnold et al. (2017) stated that automating and scaling tools that can aid students in their monitoring; i.e. awareness, feedback, and adapting self-regulation practices is complex. In this context learning analytics have a role to play. According to the definition provided in the 1st International Conference on Learning Analytics & Knowledge, learning analytics is 'the measurement, collection, analysis and reporting of data about learners and their contexts, for purposes of understanding and optimizing learning and the environments in which it occurs.' One way in which student's data and analyses can be presented to stakeholders is through the use of Learning Analytics Dashboards (Verbert et al., 2013). In contrast to the more traditional methods of provision of feedback to students, Learning Analytics Dashboards provide students a visual representation of their performance (Teasley, 2017). This allows students to view their performance and engagement, with the intention of increasing their self-reflection and self-awareness, in order to motivate learning and improve learning outcomes and retention (Schwendimann et al., 2016). Learning Analytics Dashboards use one or several visualizations to provide the stakeholder with an overview of some aspects of the learning process (Sedrakyan et al., 2019).

Information Visualization

Information visualizations are an example of external representation. Zhang (1997) describes external representation as knowledge and structure which is displayed by physical

symbols, objects or dimensions. External representations serve as a focus for learners' attention. This allows an instructor to introduce specific aspects to the learning process. Suthers and Hundhausen (2003) call this ''representational guidance": the creator of an external representation provides several aspects upon which learners should focus. This may encourage learners to work on specific aspects that might otherwise have been neglected. A similar effect is described by Mayer's (2008) multimedia principles. One of the principles describes that the learner should be supported through the materials by means of visual cues, a technique called 'signaling'. Several studies investigating the effects of different argumentation tools showed representational guidance can influence students' behaviour and learning process (Ertl et al., 2008).

'Information visualization' is a field that has inputs from many disciplines (Aparicio & Costa, 2015). A large-scale study by Borkin et al. (2013) identified design elements that make a visualization easier to recognize and found that aesthetic factors may play a major role in easily memorized visuals. A follow-up study by Borkin (2015) found that; (1 titles and supporting text should convey the message of a visualization; (2 if used appropriately, pictograms do not interfere with understanding and can improve recognition; (3 redundancy helps effectively communicate the message; and (4 a memorable visualization is often also an effective one. Furthermore, a study by Kostromina and Gnedykh (2015) indicates that visualization without text facilitate memorizing of information and the analysis process over the learning information. In their study, comics and schemes were found to facilitate information retention, the process of analysing the learning information, and the success of its application.

Specificity of information

Larkin et al. (1987) argue that less specific and less accurate visualizations have the advantage of being easy to process and easier to elaborate on. This is in line with research

that suggests simplified visualizations outperform more elaborate ones (Dwyer, 1969; Scheiter et al., 2009). Other studies show that higher learning performance is achieved when learning tasks include realistic and detailed visualizations compared to abstract representations (Arnold & Dwyer, 1975; van Gendt et al., 2001).

On a more theoretical level, it is possible to look from the perspective of cognitive load theory (CLT) compared to the more recent disfluency research (Brucker et al., 2014). While a CLT perspective generally recommends improving learning by avoiding irrelevant cognitive load (Sweller, 1988), disfluency effects aim to increase the level of attention that learners pay to a particular learning task through hard-to-perceive learning materials (Diemand-Yauman et al., 2011).

The visualizations in these studies are a representation of the study behaviour of bachelor students in a Social Sciences program at Utrecht University. In this context, the optimal specificity of visualizations has not yet been investigated. The reason for this is that these kinds of visualizations are very context-bound and tailored to the users.

Study behaviour

Study behaviour is a collection of cognitions and behaviour (Martin, 2008). According to Noble et. al. (2008) study behaviour is strongly linked with learning engagement and learning motivation. Learning engagement can be seen as a 'meta' construction. Singh (2002) states that learning engagement and learning motivation may have a reciprocal relationship. Motivation affects engagement in academic tasks and engagement further enhances interest and motivation (Pintrich, 2003).

In critical reviews of motivation and engagement research, it has been suggested that research oftentimes yields limited practical implications and applications. There is a need to devise research that advances scientific understanding and which has applied utility (Pintrich,

2003; Martin, 2009; Fredricks, 2004). Engagement is closely related to motivational goals and self-regulated learning (Fredricks, 2004).

Self-regulating capacities and well-being are connected in multiple contexts, including education (Elliot et al., 2011). In general, self-regulation involves learners who proactively direct their behaviour strategies to achieve self-set goals. They rely on affective, cognitive, motivational, and behavioural feedback to modify or adjust their strategies and behaviours when unable to initially attain their goals (Zimmerman, 2002).

Research into self-regulation and wellbeing shows effective self-regulatory techniques to promote well-being. Self-monitoring, or awareness, and evaluating has beneficial effects on the mental well-being of adolescents (van Genugten et. al., 2017). Knowledge about oneself, that's to say self-awareness, has been considered as a critically important component of metacognitive knowledge (Pintrich, 2003). From this perspective, self-knowledge is a person's awareness of her strengths and weaknesses of their cognition and learning, as well as her motivations. Self-awareness is a valuable skill for decision making since it supports the prediction of outcomes and how comfortable one would be with them (Carlson, 2013). In this sense, acquiring a deep knowledge about oneself has been associated with a range of positive outcomes in interpersonal relationships, mental and physical health (Wrosch & Miller, 2009). The school can play an important preventive role for mental problems, as it is a place where students spend a large part of their time next to their home. (Kase et al., 2017).

Research Questions

A visualization of study behavior gives a student information about his study behaviour at a glance. This can potentially lead to more awareness and behavioural adjustment, which makes it have a preventive effect. Because the design is context-bound and must be tailored to the end user, the following research question is assessed: Does the

specificity of a visualization of a student's own perception of study behaviour regulate students:

a) awareness in self-regulating study behaviour?

b) consideration of adjusting study behaviour?

c) usability experience?

These questions and the results from previous studies lead us to the hypothesis that specificity of information regulates a student's general perception of a visualization.

Method

Research Design

This study applied a quasi-experimental research design in which different participants are randomly assigned to different conditions (between subjects-design).

The independent variable is 'specificity of visualizations'. Three conditions have been created in which the degree of specificity of the visualization is different. Figure 1 shows a visual being used in condition 1 with little specificity. Figure 2 shows a visual being used in condition 2 with more specificity than condition 1, but less than condition 3. The last condition, condition 3, consists of a visualization with the most specificity of all three conditions.
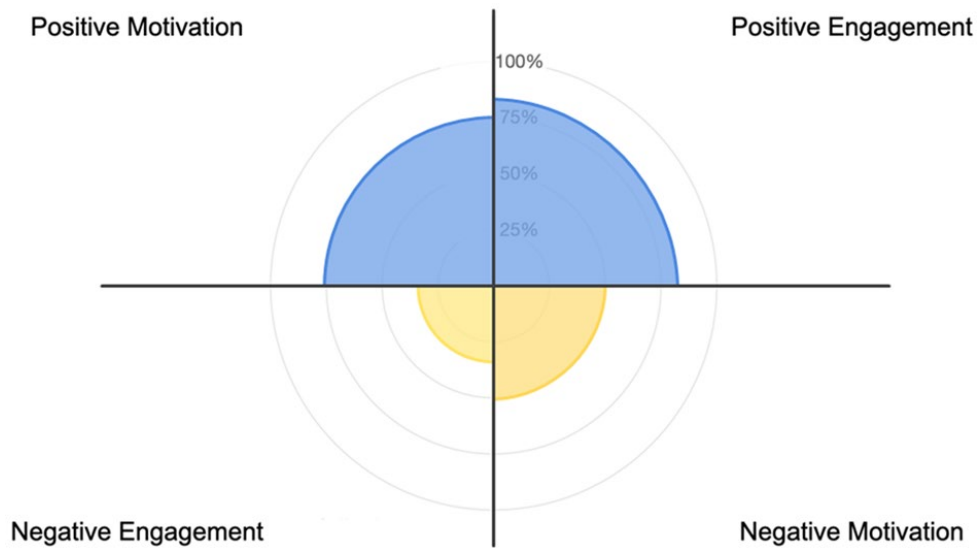
Figure 3.

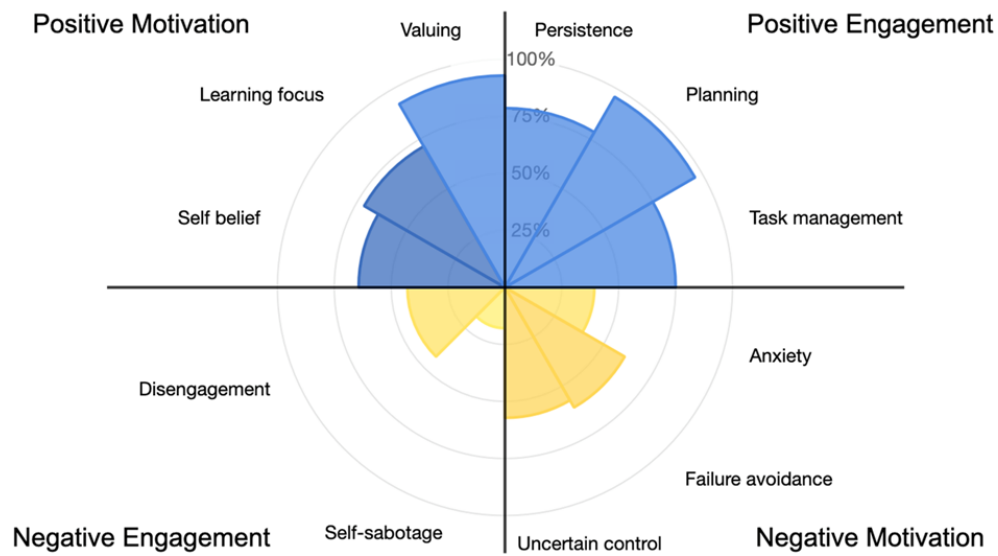*Fig. 3. Specificity level 1: only average scores per quadrant, no saturation, no text.*

Figure 4.

Fig. 4. Specificity level 2: score per subject/construct, no saturation, no text.
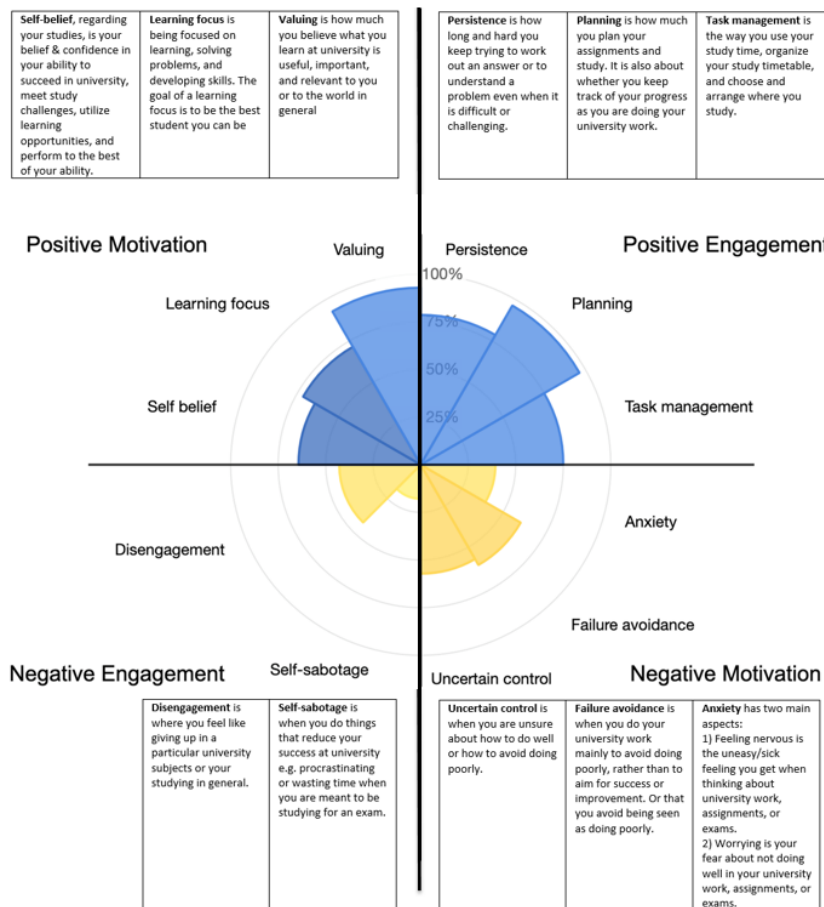
Figure 5.

Fig. 5. Specificity level 3: score per subject/construct, no saturation, with textual explanation.

For this study the software program 'Qualtrics' was used to conduct the experiment online. The questionnaire has been added as an appendix. This is a questionnaire for condition 1. The questionnaires for condition 2 and 3 have a different visualization (ie figure 4 or 5).

Participants

The participants were 46 students from Utrecht University. All participants are bachelor students. The average age was 20 (SD = 1.7). Condition 1 and condition 2 each has 15 participants, condition 3 had 16 participants.

Instruments

First participants completed the Motivation and Engagement Scale-University/College(MES-UC) questionnaire. This questionnaire has been developed to measure study behaviour. The questions asked are about positive thoughts (Positive Motivation), positive behaviours (Positive Engagement), negative thoughts (Negative Motivation) and negative behaviours (Negative Engagement). An overview of these constructs is presented in appendix 2. Figure 3, figure 4 and figure 5 presents the result of the MES-UC questionnaire. The conditions differ from each other due to the degree of detail in which the results of the MES-CU are presented in a visualization.

The level of specificity was based on research by Smulowski et al. (2018) and by consultation of project members at THERMOS, a project group from the University of Utrecht that offers students more control over their study by providing information about study behaviour.

To measure awareness in self-regulating study behaviour a questionnaire was used. A 5 point Likert scale was used, with 1 = Extremely, 2 = Very, 3 = Moderately, 4 = Slightly, 5 = Not at all over 4 items. An example of an item is: 'To what extent do you see points for improvement in the area of engagement?' A exploratory factor analysis (EFA) is performed on the items that should load on awareness. Cronbach's coefficient was used to calculate the internal consistency.

A questionnaire was used to measure consideration of adjusting his study behaviour. A 5-point Likert scale was used, with 1 = Extremely, 2 = Very, 3 = Moderately, 4 = Slightly, 5 = Not at all over 3 items. An example of an item is: 'This visual encourages me to take action to increase my engagement.' An EFA is performed on the items that should load on modification. Cronbach's coefficient was used to calculate the internal consistency.

To measure usability experience a questionnaire is used. This questionnaire is derived from the original System Usability Scale (SUS) as described by Brooke (1996). Items on this questionnaire will be scored on a 5 point Likert scale: 1 = Strongly Agree, 2 = Agree, 3 = Undecided, 4 = Disagree and 5 = Strongly Disagree. The questionnaire being used comprises 7 items, example of an item is: 'I thought the visual was easy to use.' Cronbach's alfa was used to calculate the internal consistency.

An EFA with Oblimin rotation was conducted on the 9 items for awareness and adjustment. Table 1 shows the factor loadings after rotation. The items that cluster on the same factor suggest that factor 1 represents awareness and factor 2 represents adjustment. Items 12, 14, 24 and 25 were found to load on a different construct than assumed. Items 12 and 14 It was therefore decided not to include these items in the further analysis.

Table 1. Summary of factor analysis results for awareness and adjustment

Item	Awareness	Adjustment
24 This visualization will encourage Susan to improve her motivation.	.73*	.00
25 This visualization will encourage Susan to improve her engagement.	.69*	.12
11 Should Susan pay attention to her positive motivation?	**.62**	.00
13 Should Susan pay attention to her positive engagement?	**.53**	.00
14 Should Susan pay attention to her negative engagement?	.17	.12
21 While looking at this visualization, I gained information about Susan's study behaviour.	-.13	**.74**
23 This visualization will help Susan to improve her study behaviour.	.16	**.51**
22 While looking at this visualization, I gained more insight about Susan's character.	.00	**.46**
12 Should Susan pay attention to her negative motivation?	.00	-.12

Note: *Items load on a different construct than assumed

An EFA was conducted on the 6 items for usability with Oblimin rotation. Table 2 shows the factor loadings after rotation. The items that cluster on the same factor suggest that factor 1 represents usability and factor 2 represents an unknown construct. Item 31 was found to load on a different construct than assumed. It was therefore decided not to include this item in the further analysis.

Table 2. Summary of factor analysis results for usability

Item	Factor 1	Factor 2
31 I think that I would like to use this visualization frequently.		.89
33 I thought the visualization was easy to use.	**.79**	
35 I would imagine that most people would learn to use this visualization very quickly.	**.58**	
32 I found the visualization unnecessarily complex.	**.70**	.42
34 I think that I would need the support of a tutor/teacher to be able to use this visualization.	**.72**	.36
36 I needed to learn a lot of things before I could get going with this visualization.	**.81**	.26

Note: *Items load on a different construct than assumed

Procedure

Participants were asked to join this study during an online training day at Utrecht University. Participants were informed before the study was started. All participants gave informed consent prior to joining the study (see Appendix 2 for an example form).

Participants were randomly assigned to either condition 1, 2 or 3 prior to the experiment. Participants were not aware in which condition they were assigned to. Participants in all three conditions were required to watch a video containing information about a fictional student. The video also got an explanation of the visualization, this was an empty visual. After the video they were shown a visualization with minimum, medium and maximum specific information (depending on the condition they were in). So, they received the same information, but the degree of specificity differed. Figure 6 shows an overview of the 3 conditions.
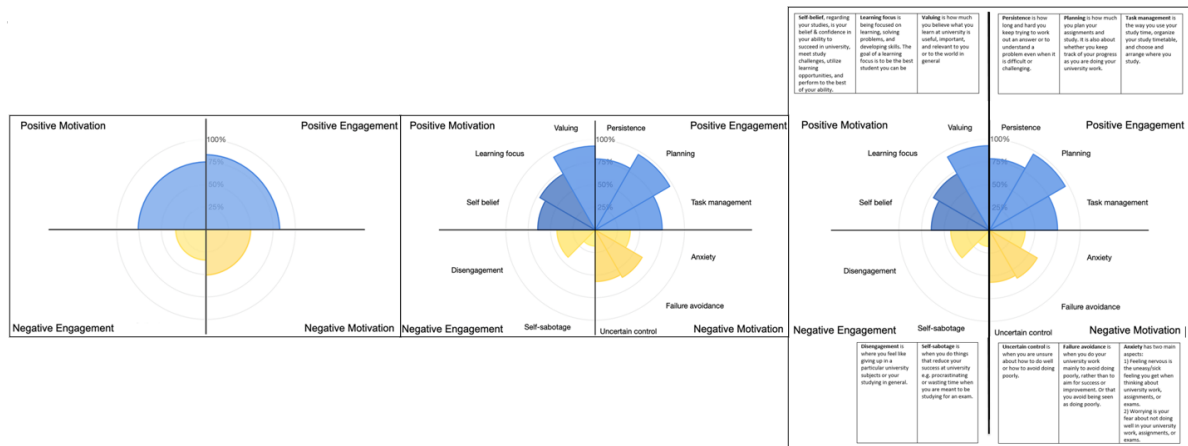
Figure 6.

Fig 6. Overview of the conditions that are used. From left to right, per condition, more specificity is displayed to the user.

While watching the visualization, participants had to fill in the questionnaire in which a) awareness in self-regulating study behaviour, b) consideration of adjusting study behaviour and c) usability is measured.

Data Analysis

The software package SPSS is used to perform this analysis. First, possible violations of assumptions have been checked for a One-way Analysis of Variance (ANOVA). The dependent variable must be normally distributed for each group. This is tested in SPSS with the Shapiro-Wilk and the Kolmogorov-Smirnov test. The assumption of homogeneity of variance will be tested with a Levene's test in SPSS. The independent variables are at the categorical level and the dependent variables are at the interval level.

Second, to compare if any difference occurs over the 3 conditions on a) awareness, b) considering adjustment and c) usability, an one-way ANOVA test is performed on each dependent variable. To test which specific conditions differ from each other, a post-hoc test is performed. This will be used to compare all groups explorative.

Results

A one-way ANOVA was conducted to compare the level of awareness, adjustment and usability between 'minimal specificity', 'average specificity' and 'maximum specificity' of information in a visualization. A statistically significant difference was found between groups, $F(2, 43) = 7.846$, $p = .001$).

A Tukey post hoc test revealed that condition 1 (the visualization with minimal specificity) judged themselves to be statistically significantly lower than condition 2 (the visualization with medium information), $p = .001$. and condition 3 (the visualization with a maximum of information), $p = .041$. There was no significant difference in score between condition 2 and condition 3. Table 3 shows an overview of the constructs measured over 3 conditions.

Table 3

Means and standard deviations

| | Level of specificity | | | | | |
| | Minimal (condition 1) | | Medium (condition 2) | | Maximum (condition 3) | |
Construct	*M*	*SD*	*M*	*SD*	*M*	*SD*
Adjustment	2.90	0.71	3.58	0.57	3.33	0.52
Awareness	2.56	0.51	2.78	0.80	2.69	0.41
Usability	3.66	0.66	4.28	0.49	4.04	0.64
Omnibus	3.03	0.44	3.55	0.29	3.35	0.35

Note: M and *SD* represent mean and standard deviation, respectively.

Awareness

The scale for 'awareness' was not reliable (two items; $\alpha = .45$). A one-way ANOVA was conducted to compare 'awareness' between the conditions with minimal, average and maximum specificity of a visualization. There was no statistically significant difference between groups, $F(2, 43) = 1.183$, $p = .316$).

Adjustment

The reliability for the scale 'adjustment' is questionable (three items; $\alpha = .57$). A one-way ANOVA was conducted to compare 'adjustment' between condition 1, condition 2 and

condition 3. There was a statistically significant difference between groups, $F(2, 42) = 4.658$, $p = .015$). A Tukey post hoc test revealed that minimal specificity was statistically significantly lower than average specificity, $p = .012$. There was no statistically significant difference in score between minimal and maximum, nor between condition average and maximum.

Usability

The scale for 'usability' is reliable (five items; $\alpha = .67$). A one-way ANOVA was conducted to compare 'usability' between condition 1, condition 2 and condition 3. There was a statistically significant difference between groups, $F(2, 42) = 3.941$, $p = .027$). A Tukey post hoc test revealed that condition 1(the visualization with minimal information) judged themselves to be statistically significantly lower than condition 2(the visualization with average information), $p = .021$. There was no significant difference in score between condition 1 and condition 3(the visualization with most information), nor between condition 2 and 3.

Discussion

The degree of specificity in a visualization matter. The present study shows that the degree of specificity of a visualization of one's own perception of study behaviour has a regulatory effect on intended behavior and usability of the visualization. The condition in which students received minimal information about their study behaviour showed a significant difference compared to the conditions in which students received an average or maximum of information. Minimal-specified visualizations leads to a low score on intended adjustment of behaviour and on usability. This result is in line with previous studies of the amount of information in visualizations. When more specificity is available in a visualization, students are more likely to adjust their behaviour. The study by van Gendt & Verhagen (2001) indicates that higher learning performance is found when learning tasks include

detailed visualizations compared to abstract representations. A representation of reality that is too simple seems to encourage less behavioural adjustment compared to a visualization with more specificity. Research on disfluency (Brucker et al., 2014), which suggests that placing higher demands on working memory, deeper processing and more analytical and extended reasoning is encouraged gave indications for this result. It seems that more data in a visualization means more comprehension of the concept to be learned.

No significant result was found between the condition with medium specificity and the condition with maximum specificity. This suggests that there is a kind of optimum of information that can be put into a visualization. As previously described by Mayer (2008), it is important to give students cues when using multimedia. In the condition with minimal specificity, there seems to be a lack of clear cues. Borkin (2015) argues that titles and supporting text should convey the message of a visualization and redundancy helps to effectively communicate the message. Although this study corroborates their conclusions, the results of this study provide no indication to an optimal application of supporting text and redundancy.

From the perspective of cognitive load theory, irrelevant information about study behaviour should be avoided (Sweller, 1988). This study does not show a threshold for the degree of information given. No difference was found between condition 2, in which sub-constructs are displayed, and condition 3, in which sub-constructs are displayed with an explanation of those sub-constructs. Kostromina and Gnedykh (2015) stated that learners might be overwhelmed by 'information overload'. Although condition 3 had a slightly lower score on awareness, adjustment and usability than condition 2, it cannot be concluded that such a kind of information overload has arisen in this condition. At most it shows some indications that medium specificity might lead to the advantage of being easier to process and

elaborate on then a maximum of information, which is in line with findings of Larkin et al. (1987).

Finally, one should consider how users interact with visualization applications. Part of this can be summed up in Schneiderman et al. (2016) visual information seeking advice "Overview first, zoom and filter, then details on demand." This is a possible explanation why no difference was found between the average specified visualization and the maximum specified visualization.

Limitations and implications for future research

During this study no focus groups were organized, although it was the intention to do so. As an implication for future research, an in-depth analysis of the results found is still needed for assessing the level of information needed. One question that this study raises is whether the outcome of the questionnaire on study behaviour affects the degree to which you are willing to adjust your study behaviour.

Future research into these types of visualizations should also focus on the way in which maximum information is presented. The optimum was not found in this study. Future research may focus on finding this optimum. Research directions might be how much information is provided at a glance, as in this study, but also to what extent students want information on demand. Explanations of the sub-constructs might become visible when the cursor is moved over the sub-constructs. In this way, the users of visualizations of study behavior can decide for themselves which subconstructs they want to zoom in on. Additional information can also be provided, such as tips to improve study behaviour.

Conclusion

When a visualization of study behaviour is designed, one should take into account that only information about the main constructs of study behavior leads to less intended adjustment of behaviour. In addition, this type of visualization is also experienced as less

useful than visualizations with medium to maximum information about study behaviour. As stated earlier, the design of a visualization and the associated choices is context-bound and tailored to the users. Choices in the design should therefore be continuously evaluated with users of the visualization.

References

Alrehiely, M. M. (2020). Evaluating Different Visualization Designs for Multivariate

Personal Health Data (Doctoral dissertation, Cardiff University).

Aparicio, M., & Costa, C. J. (2015). Data visualization. Communication design quarterly

review, 3(1), 7-11. DOI: 10.1145/2721882.2721883

Arnold, T. C., & Dwyer, F. M. (1975). Realism in visualized instruction. *Perceptual and

motor skills*, *40*(2), 369-370.

Arnold, K. E., Karcher, B., Wright, C. V., & McKay, J. (2017). Student empowerment,

awareness, and self-regulation through a quantified-self student tool. In Proceedings

of the Seventh International Learning Analytics & Knowledge Conference (pp. 526-

527). DOI: 10.1145/3027385.3029434

Borkin, M. A., Vo, A. A., Bylinskii, Z., Isola, P., Sunkavalli, S., Oliva, A., & Pfister, H.

(2013). What makes a visualization memorable?. IEEE Transactions on Visualization

and Computer Graphics, 19(12), 2306-2315. DOI: 10.1109/TVCG.2013.234

Borkin, M. A., Bylinskii, Z., Kim, N. W., Bainbridge, C. M., Yeh, C. S., Borkin, D., ... &

Oliva, A. (2015). Beyond memorability: Visualization recognition and recall. IEEE

transactions on visualization and computer graphics, 22(1), 519-528. DOI:

10.1109/TVCG.2015.2467732

Brooke, J. (1996). Sus: a "quick and dirty'usability. *Usability evaluation in industry*, *189*.

Brucker, B., Scheiter, K., & Gerjets, P. (2014). Learning with dynamic and static

visualizations: Realistic details only benefit learners with high visuospatial

abilities. *Computers in Human Behaviour*, *36*, 330-339.

Carlson, E. N. (2013). Overcoming the barriers to self-knowledge: Mindfulness as a path to

seeing yourself as you really are. *Perspectives on Psychological Science*, *8*(2), 173-

186.

Choe, E. K., Lee, B., Zhu, H., Riche, N. H., & Baur, D. (2017, May). Understanding self-reflection: how people reflect on personal data through visual data exploration. In *Proceedings of the 11th EAI International Conference on Pervasive Computing Technologies for Healthcare* (pp. 173-182).

Diemand-Yauman, C., Oppenheimer, D. M., & Vaughan, E. B. (2011). Fortune favors the (): Effects of disfluency on educational outcomes. *Cognition*, *118*(1), 111-115.

Dwyer Jr, F. M. (1969). The effect of varying the amount of realistic detail in visual illustrations designed to complement programmed instruction. *Programmed Learning and Educational Technology*, *6*(3), 147-153.

Ertl, B., Kopp, B., & Mandl, H. (2008). Supporting learning using external representations. Computers & Education, 51(4), 1599-1608. DOI: 10.1016/j.compedu.2008.03.001

Evergreen, S., & Metzner, C. (2013). Design principles for data visualization in evaluation. New directions for evaluation, 2013(140), 5-20.

Fredricks, J. A., Blumenfeld, P. C., & Paris, A. H. (2004). School engagement: Potential of the concept, state of the evidence. Review of educational research, 74(1), 59-109. DOI: 10.3102/00346543074001059

van Genugten, L., Dusseldorp, E., Massey, E. K., & van Empelen, P. (2017). Effective self-regulation change techniques to promote mental wellbeing among adolescents: a meta-analysis. Health psychology review, 11(1), 53-71., DOI:10.1080/17437199.2016.1252934

Kase, C., Hoover, S., Boyd, G., West, K. D., Dubenitz, J., Trivedi, P. A., ... & Stein, B. D. (2017). Educational outcomes associated with school behavioural health interventions: A review of the literature. Journal of School Health, 87(7), 554-562. DOI: 10.1111/josh.12524

Kersten-van Dijk, E. T., Westerink, J. H., Beute, F., & IJsselsteijn, W. A. (2017). Personal

informatics, self-insight, and behaviour change: a critical review of current

literature. *Human–Computer Interaction*, *32*(5-6), 268-296.

Kostromina, S., & Gnedykh, D. (2015). Type of visualization and quality of digestion of

educational information by students. *Procedia-Social and Behavioural Sciences*, *171*,

340-349.

Larkin, J. H., & Simon, H. A. (1987). Why a diagram is (sometimes) worth ten thousand

words. *Cognitive science*, *11*(1), 65-100.

Li, I., Dey, A., & Forlizzi, J. (2010). A stage-based model of personal informatics systems.

In *Proceedings of the SIGCHI conference on human factors in computing

systems* (pp. 557-566).

Lin, J. J., Mamykina, L., Lindtner, S., Delajoux, G., & Strub, H. B. (2006, September).

Fish'n'Steps: Encouraging physical activity with an interactive computer game.

In *International conference on ubiquitous computing* (pp. 261-278). Springer, Berlin,

Heidelberg.

Martin, A. J. (2008). Enhancing student motivation and engagement: The effects of a

multidimensional intervention. Contemporary educational psychology, 33(2), 239-

269. DOI: 10.1016/j.cedpsych.2006.11.003

Martin, A. J. (2009). Motivation and engagement across the academic life span: A

developmental construct validity study of elementary school, high school, and

university/college students. *Educational and psychological measurement*, *69*(5), 794-

824.

Mayer, R. E. (2008). Applying the science of learning: Evidence-based principles for the

design of multimedia instruction. *American psychologist*, *63*(8), 760.

Noble, T., Wyatt, T., McGrath, H., Roffey, S., & Rowling, L. (2008). Scoping study into

approaches to student wellbeing. Retrieved from

https://docs.education.gov.au/documents/scoping-study-approaches-student-

wellbeing-final-report

Pintrich, P. R. (2003). A motivational science perspective on the role of student motivation in

learning and teaching contexts. Journal of educational Psychology, 95(4), 667. DOI:

10.1037/0022-0663.95.4.667

Sanjines, S. C. (2018). Does It Make a Difference? Data Vizualizations and the Use of

Research and Evaluation Reports (Doctoral dissertation, University of Hawaiʻi at

Mānoa).

Scheiter, K., Gerjets, P., Huk, T., Imhof, B., & Kammerer, Y. (2009). The effects of realism

in learning with dynamic visualizations. *Learning and Instruction*, *19*(6), 481-494.

Shneiderman, B. (2003). The eyes have it: A task by data type taxonomy for information

visualizations. In The craft of information visualization (pp. 364-371). Morgan

Kaufmann.

Schwendimann, B. A., Rodriguez-Triana, M. J., Vozniuk, A., Prieto, L. P., Boroujeni, M. S.,

Holzer, A., ... & Dillenbourg, P. (2016). Perceiving learning at a glance: A systematic

literature review of learning dashboard research. IEEE Transactions on Learning

Technologies, 10(1), 30-41. DOI: 10.1109/TLT.2016.2599522

Sedrakyan, G., Mannens, E., & Verbert, K. (2019). Guiding the choice of learning dashboard

visualizations: Linking dashboard design and data visualization concepts. *Journal of

Computer Languages*, *50*, 19-38.

Singh, K., Granville, M., & Dika, S. (2002). Mathematics and science achievement: Effects

of motivation, interest, and academic engagement. The journal of educational

research, 95(6), 323-332. DOI: 10.1080/00220670209596607

Skulmowski, A., & Rey, G. D. (2018). Realistic details in visualizations require color cues to foster retention. *Computers & Education*, *122*, 23-31.

Somervell, J. P., McCrickard, D. S., North, C., & Shukla, M. (2002, May). An Evaluation of Information Visualization in Attention-Limited Environments. In *VisSym* (pp. 211-216).

Suthers, D. D., & Hundhausen, C. D. (2003). An experimental study of the effects of representational guidance on collaborative learning processes. *The Journal of the Learning Sciences*, *12*(2), 183-218.

Sweller, J. (1988). Cognitive load during problem solving: Effects on learning. *Cognitive science*, *12*(2), 257-285.

Teasley, S. D. (2017). Student facing dashboards: One size fits all?. *Technology, Knowledge and Learning*, *22*(3), 377-384.

Van Gendt, K., & Verhagen, P. (2001). Visual Testing: Searching for Guidelines.

Verbert, K., Duval, E., Klerkx, J., Govaerts, S., & Santos, J. L. (2013). Learning analytics dashboard applications. *American Behavioural Scientist*, *57*(10), 1500-1509.

Wrosch, C., & Miller, G. E. (2009). Depressive symptoms can be useful: Self-regulatory and emotional benefits of dysphoric mood in adolescence. *Journal of personality and social psychology*, *96*(6), 1181.

Zhang, J. (1997). The nature of external representations in problem solving. Cognitive science, 21(2), 179-217. DOI: 10.1016/S0364-0213(99)80022-6

Zimmerman, B. J. (2002). Becoming a self-regulated learner: An overview. *Theory into practice*, *41*(2), 64-70.

Appendix 1

Visualization of motivation and engagement

Q1
<u>Information for participants</u>

April 2, 2020

Dear student,

The purpose of this study is to examine whether the degree of a visualisation's specificity about a person's study motivation and engagement influences a) the interpretation of the visualization, b) the intended adjustment on study behavior and c) the usability of the visualization.

Please read the information below carefully before continuing.

Design of the study
First, you will watch an informative video, explaining the context of the visualization. Second, you are presented a visualization of Susan's study motivation and engagement. After watching the visualization, you fill in a questionnaire measuring a) understanding of the core message, b) whether and how study behavior will be adjusted and c) the usability. The questionnaire consists of 15 questions.

Confidentiality of data processing
This study requires us to collect some of your personal data. We need this data in order to be able to answer the research question properly or to be able to contact you for follow-up research.
This personal data will be stored on a different computer than the research data itself. The computer on which your personal details are stored is secured to the highest standards, and only researchers involved1 will have access to this data. The data itself will also be protected by a security code.
Your data will be stored for at least 10 years. This is in accordance with the guidelines provided by the VSNU Association of Universities in the Netherlands. Please refer to the website of the Authority for Personal Data: https://autoriteitpersoonsgegevens.nl/nl/onderwerpen/avg-europese-privacywetgeving, for more information about privacy.

Voluntary participation
Participation in this study is voluntary. You can end your participation in the study at any time, without any explanation and without any negative consequences. If you end your participation, we will use the data collected up to that point, unless you explicitly inform us otherwise.

Independent contact and complaints officer If you have an official complaint about the study, you can send an email to the complaints officer at klachtenfunctionaris-fetcsocwet@uu.nl.
If, after reading this information letter, you decide to take part in the research, please click 'agree'.

 With kind regards,

 Willem Nijmeijer
 Lars de Vreugd

1Prof. dr. M. van der Schaaf, prof.dr. S. te Pas, prof.dr. J. Jeuring, prof.dr. M. Kluijtmans, dr. R. Jansen, dr. S. Sosnovsky and dr. A. van Leeuwen.

○ Agree (1)

Page Break

Q2
Dear student,

Thank you for participating in this research! Please watch the video below before you continue.

Page Break

C1.1
Below is a visualization of Susan's study motivation and engagement.
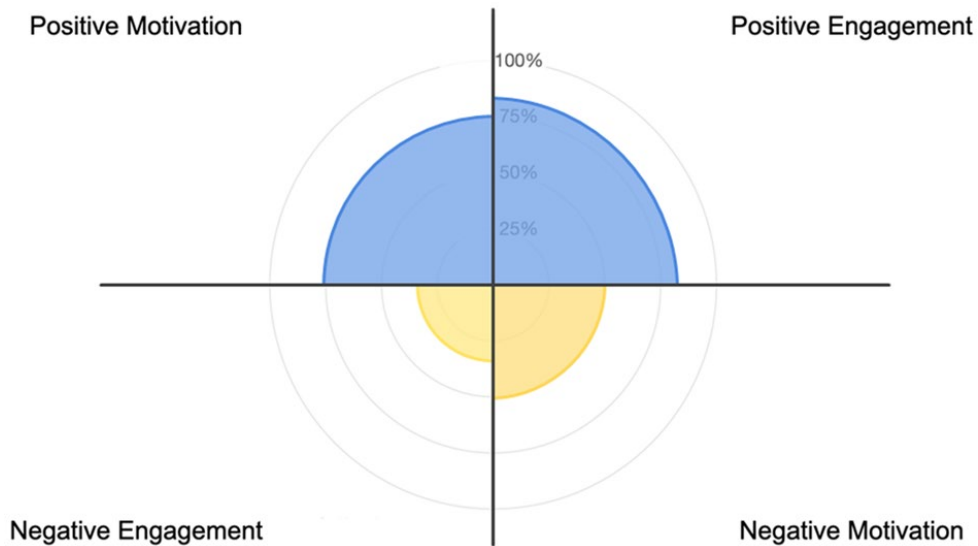
The next 4 questions are related to Susan's visualization. While looking at Susan's visualization, try to understand what you see and what this might mean to Susan.
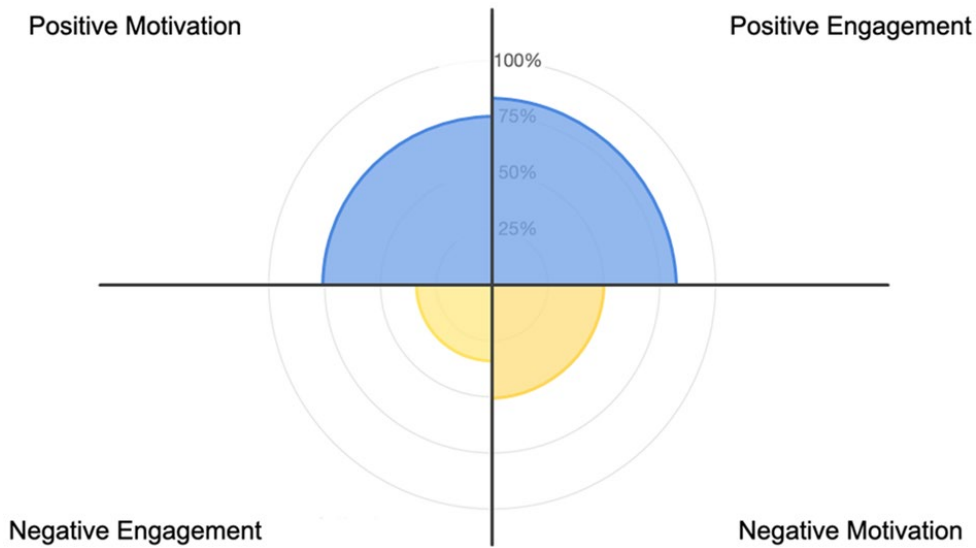
	Not at all (1)	- (2)	- (3)	- (4)	Extremely (5)
Should Susan pay attention to her positive motivation? (2)	○	○	○	○	○
Should Susan pay attention to her negative motivation? (3)	○	○	○	○	○
Should Susan pay attention to her positive engagement? (5)	○	○	○	○	○
Should Susan pay attention to her negative engagement? (6)	○	○	○	○	○

Page Break

C1.2
Below is a visualization of Susan's study motivation and engagement.

The next 5 questions are related to Susan's visualization. While looking at Susan's visualization, try to understand what you see and what this might mean to Susan.

	Not at all (1)	- (2)	- (3)	- (4)	Extremely (5)
While looking at this visualization, I gained information about Susan's study behavior. (1)	○	○	○	○	○
While looking at this visualization, I gained more insight about Susan's character. (2)	○	○	○	○	○
This visualization will help Susan to improve her study behavior. (3)	○	○	○	○	○
This visualization will encourage Susan to improve her motivation. (4)	○	○	○	○	○
This visualization will encourage Susan to improve her engagement. (5)	○	○	○	○	○

Page Break

C1.3

The next 6 questions are related to your experience with the visualization. Consider whether you would like to use this visualization for yourself with your own data.

	Strongly disagree (1)	- (2)	- (3)	- (4)	Strongly agree (5)
I think that I would like to use this visualization frequently. (1)	○	○	○	○	○
I found the visualization unnecessarily complex. (2)	○	○	○	○	○
I thought the visualization was easy to use. (3)	○	○	○	○	○
I think that I would need the support of a tutor/teacher to be able to use this visualization. (4)	○	○	○	○	○
I would imagine that most people would learn to use this visualization very quickly. (5)	○	○	○	○	○
I needed to learn a lot of things before I could get going with this visualization. (6)	○	○	○	○	○

C1.4

What is your age?

_____

C1.5

At this moment I am a...

○ bachelor student. (1)

○ pre-master student. (2)

○ master student. (3)

Page Break

THE IMPACT OF SPECIFICITY IN VISUALIZING STUDY BEHAVIOUR

Q4
Thank you for taking the time to participate in this research!

We would like to get a better insight in how you interpreted and made use of the visualization. If you would like to offer your thoughts and give your opinion, you can do so by sending an email to the address below. We will then get in touch to schedule a short interview (± 15 minutes).

 w.nijmeijer@students.uu.nl

Appendix 2

Table 1. *Overview of constructs used in Martin's Motivation and Engagement Wheel*

Construct	Description	Adapted in part from
Adaptive cognitions		
Self-efficacy	is students' belief and confidence in their ability to understand or to do well in their schoolwork, to meet challenges they face and to perform to the best of their ability.	Midgley et al.'s (1997)
Valuing school	is how much students believe what they learn at school is useful, important and relevant to them or to the world in general.	Pintrich et al. (1991)
Mastery orientation	entails being focussed on learning, solving problems and developing skills.	Nicholls (1989), Duda and Nicholls (1992)
Adaptive behaviour		
Planning	is how much students plan their schoolwork, assignments and study and how much they keep track of their progress as they are doing them.	Miller et al. (1996)
Study management	refers to the way students use their study time, organize their study timetable and choose and arrange where they study.	Pintrich et al. (1991)
Persistence	is how much students keep trying to work out an answer or to understand a problem even when that problem is difficult or is challenging.	Miller et al. (1996)
Impeding cognition		
Anxiety	has two parts: feeling nervous and worrying. Feeling nervous is the uneasy or sick feeling students get when they think about their schoolwork, assignments or exams. Worrying is their fear of not doing very well in their schoolwork, assignments or exams.	Pintrich and De Groot (1990)
Failure avoidance	occurs when the main reason students do their schoolwork is to avoid doing poorly or to avoid being seen to do poorly.	Harter, Whitesell & Kowalski (1992)
Uncertain control	occurs when students are uncertain about how to do well or how to avoid doing poorly.	Connell's (1985)
Maladaptive behaviour		
Self-handicapping	occurs when students do things that reduce their chances of success at school. Examples are putting off doing an assignment or wasting time while they are meant to be doing their schoolwork or studying for an exam.	Midgley, Arunkumar, & Urdan (1996), Strube (1986)
Disengagement	occurs when students feel like giving up in particular school subjects or in school generally. Students high in disengagement tend to accept failure and behave in ways that reflect helplessness.	Not mentioned in article.