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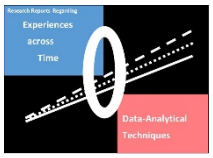

Four-Quadrant Relationship Data Analysis: An Illustrative Example

Joke H. van Velzen
Research Institute of Child Development and Education, University of Amsterdam, The Netherlands

Abstract
The aim of this article is to offer a preliminary illustration of how to employ four-quadrant relationship data analysis and, in particular, to show the identifying of inter-individual groups based on person-specific intra-individual data and the detection of conditional information. The data were obtained via four integrated mixed methods research questions that inquired about eleventh-grade senior high school students' views on homework learning (i.e., studying and memorizing) in general. However, these data were collected for a previous study on metacognitive knowledge (Van Velzen, 2021) and not specifically for this illustrative example, but they were considered suitable due to inquiring about the homework-learning situation. The participants' (N = 27) results showed how four-quadrant relationship data analysis could be employed because it enabled (a) the visualization of the relationships between quantitative, quantitized, and qualitative data, (b) the identification of inter-individual groups based on all-including person-specific intra-individual data, and (c) the detection of conditional information as well as initial conditions. It is concluded that four-quadrant relationship displays can be useful for initial data analysis to obtain a thorough understanding of all data, including emerging data.

Keywords: data-analysis technique, data understanding, integrated data, visualizing data

Introduction: Data Analysis of Situation to Detect Conditional Information

Research on the importance of the conjunction of person-situation (Furr & Funder, 2021) and person-specific or single-case intra-individual data (Molenaar, 2004) for the social and behavioral sciences has led to Van Velzen (2024a; 2024b) arguing in favor of the detection of conditional information. Conditional information, defined as additionally relevant or essential information that provides for a provision or stipulation in terms of including the word of *if*: "This will happen *if* . . ., because . . ." is thought to be meaningful to obtain an understanding of when and why certain sub-situations exist in the views and interpretations of certain groups of persons. In the social and behavioral sciences, where research on situations is closely related to personal views on and interpretations of situations, Van Velzen (2024b) argued that conditional information could provide for an understanding of how certain situational features can lead to inter-individual groups based on person-specific intra-individual data. That is, identifying inter-individual groups based on person-specific intra-individual data goes beyond the standard within- and between-person differences because it involves data analysis of all-including data (i.e., records of original observation and measurement without data cleaning and including latent and emerging data), and requires exploration via visualizations (Unwin, 2020).

When person-specific intra-individual data are taken as the basis for identifying inter-individual groups rather than the standard statistical techniques, then a data-

analytical technique is required for obtaining a thorough understanding of the data, in that it resembles complex problem solving to examine if conditional information in situations is meaningful to identify certain groups of people. To this end, Van Velzen (2024b) proposed the data-analytical technique of four-quadrant relationship display. Mathematically, four-quadrant *plots* enable the visualization of the relationship between negative and positive values (see Figure 1a), in that it is applied as a scatter plot for different pairs of data. Commonly, four-quadrant plots are displayed as graphs when the values of the two variables have multiple varying scores. That is, difference in trending ability of, for instance, two measurement methods can be plotted for pairs of delta values (e.g., two testing values at sequential time points, for instance, a second value time point minus the first value time point of two measurement methods) to compare these two measurement methods (Bataille et al., 2012; Proença et al., 2019). Other kinds of values that have been analyzed via four-quadrant plots are correlational values (Marciano & Yeshurun, 2017) and thematic distinctions (Jang et al., 2023). This raises the question of whether it can be suitable for analyzing mixed methods research and emerging data. In this article, the translation of the four-quadrant plot into the so-called four-quadrant relationship display (see Figure 1b) for mixed methods research data (i.e., numerical values and distinctive thematic concepts) is examined.

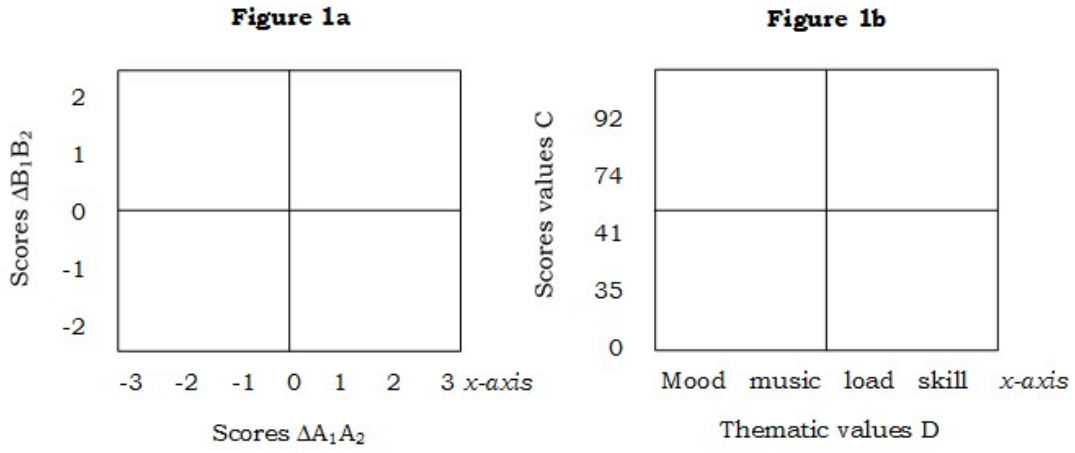

Figure 1. Schematic presentation of the mathematical four-quadrant plot (a) and the proposed four-quadrant relationship display (Van Velzen, 2024b).

In this illustrative example, the four-quadrant relationship display as a data-analytical technique is not meant to produce per se agreeable versus not-agreeable information because it is meant to visualize the connection between different scores regarding the position of multiple persons or individual participants in the quadrants. In this respect, the data can consist of a combination of nominal, ordinal, and interval measurement scales and qualitative data. The aim of this illustrative example is to illustrate the possibilities and challenges of four-quadrant relationship displays as a data-analytical technique for mixed methods research data. To this end, the research subject is the identification of groups of eleventh-grade high school students in line with their views and interpretations of the homework-learning situation (i.e., studying and memorizing of one's own accord in general) based on all-including person-specific

intra-individual data.

Theoretical Framework

First of all, the data for this illustrative example of four-quadrant relationship data analysis were not collected for the purpose of studying conditional information in situations in relation to persons. The data were collected for a study on homework and metacognitive knowledge (Van Velzen, 2021), and as such it did include homework-learning situations and eleventh-grade senior high school students' views and interpretations about their homework-learning situation in general. Because, in the end, the data employed in this illustrative example had not been needed for the study on metacognitive knowledge and, hence, were neither analyzed nor published elsewhere, it raises the question of whether the unused collected data of the previous study could be employed for this illustrative example.

Detecting conditional information in homework-learning situations, as these situations are viewed and interpreted by persons, in order to establish differences in those views and interpretations that warrant the identification of inter-individual groups, the questions of the previous study were examined against the theoretical framework of conditional information in situations (see Van Velzen, 2024b, for a theoretical substantiation). The theoretical framework (see Figure 2) presents the interconnections of a person who experiences the events of a situation.

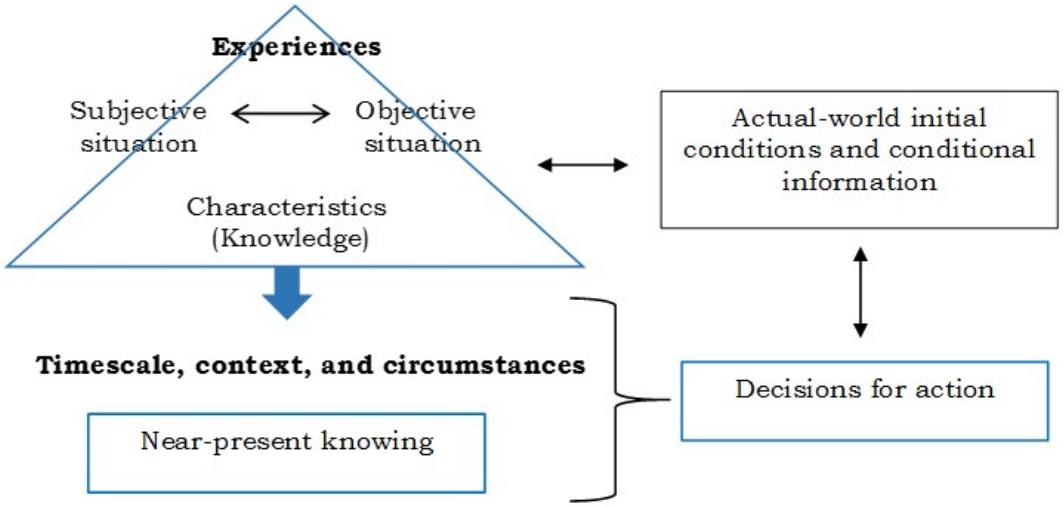

Figure 2. Theoretical framework of actual world situations and their features across time (in black) in relation to human interpretation (in blue). (Van Velzen, 2024b).

Figure 2 shows that, generally, persons' experiences about the actual world consist of their objective or overall agreed-upon views on the situation and each person's subjective view based on interpretations regarding timescales, context, and circumstances (Van Velzen, 2023a; 2023b). Timescales, context, circumstances, and their changes across time lead to a person making decisions for behavior and action. Hence, the initial conditions (i.e., starting point-values for variables) and conditional information that are found for groups of persons can be assumed to be actually there because the actual situation led to the views and interpretations as experienced by

groups of persons.

The theoretical framework in Figure 2 needed to agree with the questions (see Appendix A) from the previous study to be able to employ these questions for this illustrative example. Specifically, the questions needed to inquire or at least hint to the theoretical concept of characteristics (i.e., knowledge about oneself and the world, including learning) in connection to varieties in homework-learning situations (see Thao et al., 2021; Van Velzen, 2022, for overviews) and this was the case (see Instruments for a theoretical account). Unfortunately, the questions did not refer to timescales, context, and circumstances. The research questions for this illustrative example were as follows.

1. Can the four-quadrant relationship data-analytical technique include mixed methods research data (i.e., quantitative or numerical, quantitized or hierarchically and ordered verbal, and qualitative or verbal and thematic)?
2. Can the four-quadrant relationship data-analytical technique enable the identification of inter-individual group(s) based on person-specific intra-individual data via conditional information of situations?

Method

Participants

The participants were 11th-grade senior high school students and they filled in integrated closed- and open-ended questions that inquired about their homework learning in general. Their high school provided for mentor courses that were designed to teach the students how to take responsibility for their own homework learning by planning their learning, performing learning techniques (e.g., summarizing and memorizing) appropriately, and to reflect on their learning. In the Netherlands, it is customary to teach students to take responsibility for their own learning since it has become government policy in 1993. The participants participated because their teachers had reacted to the call for research and their parents had given consent for participation.

The sampling method for this illustrative example consisted of selecting only those participants (n = 27) from the previous research (N = 73) that had (a) completely filled in the questions about homework learning in general (see Instruments) and (b) gave an open-ended response with a word count of > 55 words to obtain sufficiently rich qualitative data that could provide for meaningful information. The participants (18 women, 9 men, M_{age} = 16.78 years, age range: 16-18 years) had an educational profile (i.e., major subjects) regarding the sciences (n = 21), languages and arts (n = 3), and economy and society (n = 3).

Procedure

Data collection had consisted of the researcher introducing the questions to the participants in a collective gathering at their schooling institution by explaining the aim of the study (i.e., gaining insight into when and why students think about their homework learning as they do, individually), and by emphasizing anonymity (i.e., only the researcher will see the participants' responses and will publish it without revealing who they are), implications (i.e., there are no correct responses, only individually

preferred ways of homework learning), and the essentiality of responding truthfully and comprehensively. Immediately after the introduction, the participants had filled in the questions. Hence, the questions were new to all participants because there was only one data-collection moment for all participants at the same time.

Regarding experimental manipulations or interventions, the participants neither were trained in learning nor received specific instruction about how to respond to the questions because the aim of these questions was to collect individual descriptions, as comprehensively as possible, about homework learning in general.

Instruments

There were two kinds of questions. The first kind of questions consisted of four open-ended items that inquired about demographic information (i.e., name, age, sex, and educational profile or study subject). The second kind of questions consisted of four questions about the participants' views on homework learning in general and their homework-learning behavior specifically (see Appendix A). Each question had four sub-questions that consisted of closed-ended questions to choose a response (i.e., "Please, select one of the four options"), which was followed by a related open-ended question to allow the participant to add information in their own words (i.e., "Please, give an example"). Hence, the questions were integrated mixed methods research questions because the content of each closed- and open-ended question depended on one another (Yin, 2006).

The four questions about homework learning, labeled in the tables as Q1-Q4, each including four closed-ended sub-questions, that were labeled a, b, c, and d, that provided for quantitative or numerical information, and that inquired about two overall homework-learning habits, namely students who do and those who hardly think through their learning and put effort into their learning because, as aforementioned, the focus of the previous study was on metacognitive knowledge and students need to consider and put effort into planning and reflecting about their learning situations in order to develop metacognitive knowledge (Brown, 1987). The closed-ended sub-questions did not exclude one another because the participants were also enabled to clarify their response via the open-ended follow-up question.

The four questions about homework learning inquired about (a) the manner of homework learning in general, (b) the impact of marks on homework learning, (c) the focus on certain learning features during homework learning, and (d) the manner of learning for difficult learning tasks during homework. More specifically, the manner of homework learning in general was defined as the individual differences in personal learning experiences (Maier & Klotz, 2022; Shemshack & Spector, 2020), learning activities (Dunlosky et al., 2013; Donoghue & Hattie, 2021), and mental cognitive activity (Opdal, 2022), and it was operationalized as individual student's overall homework-learning purpose and behavior. The impact of marks on homework learning was defined as involving effort, interest, and learning preferences (Thao et al., 2021) and time management (Brooker et al., 2017), and it was operationalized as the main homework-learning attitude to obtain very good, passing, and failing marks. The kinds of learning features that students can focus on during homework learning were defined as concentrating (Serences & Kastner, 2014), controlling of distractions (Schmidt, 2020), short- and long-term memorizing (Norris, 2017), managing time (Brooker et al., 2017), and (self-) reflecting and maintaining autonomy (Wiersema & Licklider, 2007), and it was operationalized as having an influence or impact on learning during homework.

Finally, the manner of homework learning when learning tasks are complex or extra difficult was defined as involving kinds of effort (Rach & Heinze, 2011), and it was operationalized as effortful behavior that affects homework learning.

Research Design

To obtain answers to the descriptive research questions of the previous study, the one-group multiple-posttests design had been employed by collecting integrated mixed methods research data around March of the school year because it enabled an examination and interpretation of metacognitive knowledge, which is known to develop slowly.

Data Analysis

All participants received a number to guarantee their anonymity in this publication. The quantitative data consisted of the first four letters of the alphabet similar to the closed-ended sub-questions. The responses to the open-ended questions were copied completely into transcripts, which were analyzed into quantitized and qualitative data via content data analysis. The quantitized data consisted of those open-ended responses that produced either categorical data to which numbers could be assigned (i.e., nominal measurement scale) or that could be ordered hierarchically (i.e., ordinal measurement scale). The qualitative data consisted of a word and several words in the open-ended responses that provided for a particular meaning and theme, but it was not possible to assign numbers (i.e., hierarchy and ordering) to these words and themes. Inter-rater reliability was not obtained because the results were not meant to contribute to learning theory, the results merely intent to illustrate the four-quadrant relationship data-analysis technique.

Results

The open-ended responses of the participants provided for general descriptions about their views on and interpretations of homework-learning situations, showing an average word count per response of 74 words (*SD* = 14 words; range 56-99 words).

In this illustrative example, the results of all four-quadrant relationship data analysis are displayed into a table format because the questions employed in this illustrative example did not provide for multiple, small measurement units that could be visualized better via an x-axis and y-axis. The quadrants are straightforward in having one and two subdivisions rather than multiple subdivision (see Table 1a).

Table 1a

Lay Out of the Four-Quadrant Relationship for Displaying the Position of Participants in tables

		First kind of data
Second kind of data	Quadrant I	Quadrant II
	Quadrant III	Quadrant IV

The closed-ended sub-questions inquired about two overall homework-learning habits, namely with and without considering and putting effort into homework learning (see Table 1b).

Table 1b

Characteristics of the Closed-Ended Sub-Questions as They are Ordered by Considering and Putting Effort into Homework Learning (With) or Not (Without)

Question	**With**		**Without**	
1	b	d	a	c
2	b	c	a	d
3	a	d	c	b
4	b	d	a	c

The position of the participants based on the selected responses to the first and second closed-ended sub-questions are placed in the standard format of the four-quadrant relationship display (see Figure 2a) by ordering the questions into higher and lower learning quality (Bransford et al., 2000). Higher quality of learning consisted of considering one's learning and putting effort into learning, whereas lower quality of learning was defined as not considering nor putting effort into learning.

Table 2a

Individual Participant Positions for the Relationship Between the Q1 and Q2 Choices

		Q1*						**Q1^**			
		b			**d**			**a**		**c**	
Q2*	**b**	61	64	65	6 57	17	30	20			
	c	21 36	23 60	28	11 66	29 70	31	53		19	37
Q2^	**a**	34			55					8	12	71
	d							52			

Note. Q1 = First question: The manner of homework learning in general. Q2 = Second question: The impact of marks on homework learning. * = Considering and putting effort into homework learning. ^ = Not considering and not putting effort into homework learning.

Table 2a shows the standard four-quadrant relationship data-analysis display. The first quadrant lies in the left upper corner and it shows the relationship between Q1 b, d, and Q2 b, c, both involving the considering of and putting effort into home-work learning. The second quadrant lies in the right upper corner and it shows the relationship between Q1 a, c, and Q2 b, c, of which Q1 involves the not-considering of and not-putting effort into homework learning, whereas Q2 involves the considering of and putting effort into homework learning. Conversely, the third quadrant in the left

lower corner shows the relationship between Q1 b, d, and Q2 a, d, for considering and putting effort into homework learning and not doing so, respectively. Quadrant four lies in the right lower corner and shows the relationship between Q1 a, c, and Q2 a, d, both involving not-considering of and not-putting effort into homework learning. The results of Table 2a show that most participants were placed in the first quadrant, implying the considering of and putting effort into learning regarding the manner of homework learning in relation to the impact of marks on homework learning.

Table 2b

Individual Participant Positions for the Relationship Between the Q1 – Q4 Choices

		Q1*				**Q1^**				**Q2***				**Q2^**			
		b			**d**	**a**			**c**	**b**			**c**	**a**			**d**
Q4*	**d**	15		1	3	7	18	2	16	1	7	3	11	2			
				11	23					23	24	15	16				
				24	25							18	25				
	b	8	9	5	26	17		4	27	5	22	8	9	4	14		
		10	14									10	26	27			
		22															
Q4^	**c**	21		12	13			6		12	20	13	21	19		17	
				19	20							55					
	a																
Q3*	**d**			1	26	7				1	7	26					
	a	8	14	11	20			4	16	20	24	8	11	4	14		
				24				27				16		27			
Q3^	**c**	10	15	5	12			6		5	12	6	10				
		22		13	25					22		13	15				
												25					
	b	9	21	3	19	17	18	2		23		3	9	2	19	17	
				23								18	21				

Note. Q1 = The manner of homework learning in general. Q2 = The impact of marks on homework learning. Q3 = The kinds learning features that are focused on during homework. Q4 = The manner of homework learning when learning tasks are complex or extra difficult. * = Considering and putting effort into homework learning. ^ = Not considering and not putting effort into homework learning.

Table 2b shows a four-times-four-quadrant relationship data-analysis display regarding the remaining closed-ended sub-questions in relation to one another by ordering the questions into higher and lower learning quality (Bransford et al., 2000). Similar to Table 2a, quadrant I agrees with the theory of higher-quality learning (i.e., considering and planning homework learning, analyzing and self-reflecting on practicing and test results, concentrating completely during learning, putting effort into difficult subject matter, and attempting to understand difficult subject matter). Quadrant IV agrees with lower-quality learning, and the Quadrants II and III represent a mixed-quality learning.

Table 3

Individual Participant Positions for the Relationship Between the Q1 Quantitative and Quantitized Data Analysis Regarding "It Differs Per Subject"

Quanti-tative		**Quantitized Q1**					
		Learning focus on				***Learning technique***	
		High Marks	**Sense**	**Pass mark**	**Time**	**≥ 2**	**1**
Q1*	**d**	1 25	13	20		3 5 11 12 13 19 24 26	1
	b		21	9	15	8 10 14 15 21 22	
Q1^	**c**			4 6 16 27			2
	a	7 18		17			7

Note. Q1 = The manner of homework learning in general. Q1-a = I am good in memorizing. Q1-c = I do what is minimally required. Q1-b = I put extra effort into homework learning. Q1-d = I study until I understand everything. * = Considering and putting effort into homework learning. ^ = Not considering and not putting effort into homework learning.

Table 3 shows a two-times-four-quadrant relationship data-analysis display regarding the often-made response of the participants (n = 21; 78%) of "It differs per subject." This kind of response was characterized as an initial condition because it is a starting point value for most participants. The responses were ordered hierarchically, beginning with the lowest order of merely mentioning memorizing abilities and the amount of learning techniques employed up to mentioning the focus or goal for learning. The evidence for the hierarchies comes from Dunlosky et al. (2013) and Donoghue and Hattie (2021), in that (a) learning techniques' usefulness depend on the

task, the phase of the learning process, and the correct performance of the technique, and (b) memorizing is essential for learning as distributed or spread out practice and deep-level or learning-for-understanding.

Table 3 shows that the amount of learning techniques employed were ordered hierarchically as lower and higher. The dividing line for the amount of learning techniques employed was two or more because, higher-quality learning (Bransford et al., 2000; Donoghue & Hattie, 2021; Dunlosky et al., 2013) most of the time requires several different learning techniques. Regarding the focus of learning, the hierarchy from lower to higher involved spending time (i.e., learning longer, starting earlier, and making a planning), getting passing marks (i.e., passing is sufficient), making sense (i.e., learning-for-understanding and connecting subject matter), and high marks (i.e., wanting to get high grades rather than passing marks, which requires higher-quality learning).

Table 4

Individual Participant Positions for the Relationship Between the Q2 Quantitative and Quantitized Data Analysis Regarding "The Impact of Marks on Homework Learning"

Quanti-tative		**Quantitized Q2**											
		Improving learning by						***Test preparation by***					
		Planning			**More time**			**Sense**			**More time**		
Q2*	**b**	1	5	12	7			24					
		20	22	23									
		24											
	c	3	6	8	9	10		10	25		9	11	26
		11	15	16									
		18	21										
Q2^	**a**				2-	4-	14-						
					19-	27-							
	d							17					

Note. Q2-a = I will think "too bad." Q2-b = I will always think about improving my learning. Q2-c = I will study longer. Q2-d = My learning is good as it is. * = Considering and putting effort into homework learning. ^ = Not considering and not putting effort into homework learning.

Table 4 shows a two-times-four-quadrant relationship data-analysis display regarding the second question of the impact of marks on homework learning. The open-ended responses indicated two nominal categories, namely improving learning in general and preparing for tests. The first category could be divided into the two hierarchically ordered categories, namely planning (i.e., higher level) and taking up more time (i.e., lower level). The second category provided for the hierarchical categories of making sense of subject matter (i.e., higher level) and taking up more

time (i.e., lower level).

Specifically, the categories of taking up more time were interpreted as being of a lower level in the hierarchy because they came without further specifications regarding purpose or goal. An example is “Because mathematics is always difficult for me, I begin to learn earlier to have more time to do mathematics.” Conversely, the category of planning referred to specific actions to be undertaken to plan another kind of learning. An example is “If my marks are not to my liking, then I examine if, for instance for physics, I can adjust the learning for the proportion of understanding the theory and practicing.” Similarly, the category of making sense of subject matter as knowing if subject matter is not understood well enough, had to be expressly specified in the responses to infer the meaning of sense making. An example is “Mathematics and chemistry never go very well, which is why I try something different every time to accomplish improvements.” Another example that indicates the making sense of subject matter through extra practicing rather than spending merely more time is “I am not good in mathematics, so I begin earlier and do extra practice tasks.”

Table 5

Individual Participant Positions for the Relationship Between the Q1 Quantitized Data Analysis of “It Differs Per Subject” and the Q3 Quantitized Analysis of “The Focus on Learning Features During Homework”

Quantitized		**Quantitized Q3**									
		Quietness			**Place**			**Interest**		**Duration**	
Q1 Marks	**High**	*11*	25					18		*7*	
	Pass				*20*			9		*20+*	
Q1 Techniques	**≥ 2**	8 *15* *26*	*11* *21*	14 22	6 *21*	*10* *26*	*15*	3-	13+	*10+* 24+	19-
	1							1		2+	*7*

Note. Q3-a = I am completely concentrated. Q3-b = I want to do other things. Q3-c = I can memorize easily. Q3-d = I always reckon with improving my learning techniques. Italics = Having more than one position.

Table 5 shows the quantitative data analysis of Q3 in relation to the quantitized results of the first question. Notably, the quantitized Q3 data are displayed in a four-quadrant relationship display because the data analysis provided for related sub-themes, such as place and quietness were related in terms of referring to a specific environment, and sense and interest were related in terms of differentiating between what triggers engagement in homework learning. As such, these four quantitized themes show a hierarchy because, for instance, quietness and place created a theme with two sub-themes, of which quietness (i.e., to minimize distractions; Schmidt,

2020) was more explicit in line with theoretically supporting learning than place was. Consequently, the participants can be positioned in the four-quadrant relationship display at more than one position because the sub-themes can refer to various kinds of quantitized results (i.e., presented in italics in Table 5). To indicate that the positions can differ in meaning, the symbols of + and – were used for, respectively, positive responses (e.g., "I can memorize easily" and "Home is the best place to learn") and negative responses (e.g., "I cannot memorize for a long period of time" and "I don't want to spend too much time on homework"). The lack of the symbols + and – indicates that it is neutral (e.g., "I study at home").

The category of place refers to home and library. The category of quietness, which refers to not wanting to be disturbed in order to learn and learning requiring concentration, was mentioned relatively often in relation to using two or more learning techniques. An example is "At home I can work and concentrate properly." The category of duration refers to the amount of time spend on homework (e.g., "When I do homework, it takes a lot of time," "I do not want to spend too much time on homework," and "I take breaks often"). The category of interest refers to being either interested in the subject matter or learning by put effort into doing homework. Examples are "I devised a new way to memorize words because the old method did not work" (i.e., +) and "I do not like the subject of physics, I find it boring and difficult to do the homework" (i.e., –).

Table 6

Individual Participant Positions for the Relationship Between the Q2 Quantitized Data Analysis of "The Impact of Marks on Homework Learning" and the Q4 Qualitative Data Analysis of "The Manner of Homework Learning When Learning Tasks are Complex or Extra Difficult"

Quantiz		**Qualitative Q4**											
		What I do											
		Sense/Interest			**Extra/Basics**			**OK mark**			**More time**		
Q2 Improving	**Plan**	*1*	8	*11*	*1+*	6+	*12+*	*11*	13	*15*	3+	*24+*	
		12	*15*	*16*	*15+*	*16+*	20-	*23*					
		21-	*23*	*24*	*23+*								
	Time	4	*25*		*10-*	19-					2-	*7+/-*	
											9+	*10+*	
											27+		
Q2 Preparation	**Sense**	*24*	*25*		*10+*	17+	*25+*	*17*			*24+*		
	Time	*11*			*9+*			*11*	26				

Note. Quantiz = Quantitized. Q2 Improving = For learning. Q2 Preparation = For tests. Italics = Having more than one position.

Table 6 presents a qualitative data analysis, in that it shows the quantitized results of the second question in relation to the qualitative data analysis of the fourth question. However, Table 6 does not present the participants' position in a four-quadrant relationship display because the analysis did not provide for related sub-themes. The participants could be placed in more than one position (i.e., presented in italics), and differences in meaning were presented via the symbols of + for positive responses, – for negative responses, and the lack of a symbol for neutral responses. Importantly, the themes obtained through the qualitative data analysis of the fourth question were essential to identify inter-individual groups in the final analysis (see Table 9) and to detect conditional information.

The category of sense/interest referred to homework learning by making sense of subject matter and learning because of being interested in either the subject matter or the learning of subject matter sufficiently. Examples are "If I do not understand subject matter during homework, then I will not understand the test questions" and "If the subject matter is not interesting, then I cannot concentrate." The category of extra/basics referred to focusing on doing the very minimum versus extra learning tasks and practicing. Examples are "When the learning tasks are difficult, then I try to do those tasks that are required minimally" and "I am not good in physics, therefore, I always do extra tasks in order to obtain a passing mark," respectively. The category of OK marks referred to doing homework merely to achieve passing marks. An example is "I do not like learning and I think that a passing mark is sufficient." The category of more time referred to putting extra time into homework learning. Examples are "I study until I understand it all: A lot of time goes into it" and "I put a lot of time in difficult subject matter, provided that I do not get too tired."

Table 7 shows each individual participant's positions regarding the quantitative (i.e., presented in black) and quantitized (i.e., Q1 presented in italics and Q2 via underlined) scores as obtained in the four-quadrant relationship data analysis (see the tables 2, 3, 4, and 5) by tallying the amount of times that the participant was in a certain quadrant. For example, Participant 1 is in quadrant I for four times regarding the four closed-ended quantitative questions, and once regarding the quantitized analysis of Q2. The quantitized analysis of Q1 for Participant 1 is in quadrant II, which is indicated via the quadrant III in italics. Another example is Participant 3, who is in quadrant I for two times regarding the four closed-ended quantitative questions, and once regarding the quantitized analysis of Q1. The quantitized analysis of Q2 for Participant 3 lies in Quadrant III. Participants with few positions and positions in more than two quadrants do not present the kinds of quadrants in which they are positioned.

The summarized results of the four-quadrant relationship displays presented in this illustrative example raise the question of how to interpret the varying participant positions in Table 7.

Table 7

Summary of Individual Participant Positions for the Closed-Ended Sub-Questions and Quantitized Data

	Quadrant I				Quadrant II				
P	1	*3*	5	7	1	2	4	7	9
T	1111<u>1</u>	11*1*	1*1*<u>1</u>	11	*1*	11	1111	11<u>1</u>	*1*
Q	*II*	<u>III</u>	III				*IV*	*IV*	
P	8	9	10	11	14	15	16	17	18
T	111*1*	1	1*1*	1111*11*	11	*1*	11	1	1
Q	<u>III</u>			<u>III</u>					
P	12	13	14	15	20	27			
T	*1*<u>1</u>	*1*	11*1*	11*1*	*1*	1111			
Q						*IV*			
P	16	17	18	19					
T	11	1	1	*1*					
Q									
P	20	21	22	23					
T	11<u>1</u>	*1*	11*1*<u>1</u>	11<u>1</u>					
Q			III						
P	24	*25*	26						
T	1111*1*<u>11</u>	11*1*	111*1*						
Q		<u>III</u>							

	Quadrant III				Quadrant IV				
P	*3*	5	6	7	2	4	6	7	9
T	11<u>1</u>	11	11<u>1</u>	*1*	11*1*<u>1</u>	*1*<u>1</u>	11*1*	*1*	<u>1</u>
Q									
P	8	9	10	11	10	14	16	17	18
T	<u>1</u>	11	11<u>1</u>	<u>1</u>	<u>1</u>	<u>1</u>	*11*	111*1*	1
Q			<u>IV</u>					*III*	
P	12	13	15	17	19	27			
T	1111	1111	11<u>1</u>	*1*<u>1</u>	11<u>1</u>	*1*<u>1</u>			
Q					*I*				
P	18	19	20	21					
T	1*1*<u>1</u>	11	11	1111<u>1</u>					
Q				*I*					
P	22	23	*25*						
T	11	11	11<u>1</u>						
Q									

Note. P = Participant. T = Tally of participant position in the quadrant. Q = Quadrant. Black = The quantitative scores (Table 2). Italics for participant number = More than one position for the quantitative scores. Italics = The quantitized Q1 scores (Table 3) and regarding which quadrant. Underlined = quantitized Q2 scores (Table 4) and regarding which quadrant.

Let us begin by summarizing the most obvious results. Table 8a shows these most obvious results, namely the four kinds of comparable results of Quadrant I. That

is, three participants, 1, 11, and 24, are in Quadrant I with the four-times maximum scores of the closed-ended quantitative questions and they all have one or more of either Q1 or Q2 scores. The participants 8 and 26 are in Quadrant I for the same reason except that they have three times the closed-ended quantitative scores, and Participant 22 has two quantitative scores, but also one Q1 *and* one Q2 score, which makes a total of four scores. The participants 14, 15, 20, and 23 all have two times the closed-ended quantitative scores and one or more of, either the Q1 *or* Q2 scores. Of the latter group, the participants 3 and 25 are also positioned in Quadrant III, which questions their position in Quadrant I as their main positioning. Participant 5 has quantitative and both Q1 and Q2 scores.

Table 8a

Overview of the Quantitative and Quantitized Results in Quadrant I per Participant

Participant				Tally	First impression
1	11	24		1111 *1*/1	Correct
8	26	*22*		11/1 *1*/+1	Likely correct
14	15	20	23	11 *1*/1	Maybe correct
5				1*1*1	Maybe correct
3	25			11*1*	Different?

Note. Italics = The quantitized Q1 scores (Table 3). Underlined = quantitized Q2 scores (Table 4).

The results in Table 8a raises two questions, namely whether it is correct or justifiable to include the quantitized results substantially in the decision criteria for inter-individual clustering and how to deal with the participants 3 and 25. A twofold procedure seems warranted. First, to describe the meaning of the scores for Quadrant I and, second, to compare the scores of Quadrant I with the scores of the other three quadrants (see Table 8b-d) in search of a pattern. First, the Quadrant I closed-ended quantitative scores meaning indicate higher-quality learning in term of learning and considering one's learning by focusing on understanding subject matter, by applying two or more learning techniques, by knowing to need a quiet place to concentrate, and by tackling difficult subject matter by putting effort into it. The quantitized Q1 scores in the first quadrant indicate the intention or goal to gain high marks, to understand subject matter thoroughly, and to employ several learning techniques. The quantitized Q2 scores in the first quadrant indicate the intention or goal to improve learning by making a planning and to prepare for tests by understanding subject matter rather than merely taking more time to learn. Furthermore, the participants 8 and 11 scoring of Q2 in Quadrant III indicates that they also focus on improving homework learning by planning and preparing for tests via understanding subject matter, but not always, whereas the participants 1, 15, and 20 scoring of Q1 in Quadrant II indicates that they focus more on passing marks and by spending more time only if it is necessary.

Second, the tables 8b up to and including 8d show the results of the remaining three quadrants. At first glance, only Table 8c provides for sufficient participants to consider it as an inter-individual group. Dissimilar to Table 8a, the first impression of a likely correct result in Table 8c because of showing a minimum of four scores in Quadrant III is missing. Also, the participants 12, 13, and 21 have quantitized Q1 scores in Quadrant I, which means that these participants find learning for high marks, understanding subject matter, and using several learning techniques important, whereas the participants 10 and 25, merely improve learning and prepare for tests by taking more time to learn. If one inter-individual group consists of those

participants who often engage in higher-quality learning (i.e., HQL+; the participants 1, 5, 8, 11, 24, and 26) because they are positioned in Quadrant I and additionally have quantitized Q1 and Q2 positions in Quadrant III, and another inter-individual group consists of those participants who sometimes engage in higher-quality learning (i.e., HQL~; the participants 12, 13, 18, and 21) because they are positioned in Quadrant III and additionally have quantitized Q1 and Q2 positions in Quadrant I, then the decision criteria are as follows. The closed-ended quantitative questions need to present in the main quadrant (i.e., I and III) three or more scores and the quantitized Q1 and Q2 positions have to be present in either the main or the alternative quadrant (i.e., I and III). If the qualitative data analysis also implies that these participants form one group rather than two slightly different groups, then the participants 3 and 25 will require further data analysis.

Table 8b

Overview of the Quantitative and Quantitized Results in Quadrant II

Participant			Tally	First impression
4	27		1111	Maybe correct
7			11<u>1</u>	Maybe correct

Note. Italics = The quantitized Q1 scores (Table 3). Underlined = quantitized Q2 scores (Table 4).

Table 8c

Overview of the Quantitative and Quantitized Results in Quadrant III

Participant			Tally	First impression
12	13	21	1111 *1*/<u>1</u>	Correct
6	10	15	11 <u>1</u>	Maybe correct
18			1*1*<u>1</u>	Maybe correct
3	25		11 <u>1</u>	Different?

Note. Italics = The quantitized Q1 scores (Table 3). Underlined = quantitized Q2 scores (Table 4).

Table 8d

Overview of the Quantitative and Quantitized Results in Quadrant IV

Participant			Tally	First impression
17			111 *1*/<u>1</u>	Correct
2	6	19	11 *1*/<u>1</u>	Likely correct

Note. Italics = The quantitized Q1 scores (Table 3). Underlined = quantitized Q2 scores (Table 4).

Next, Table 9 adds the results of the qualitative data analysis (see Table 6) to the summarized scores in Table 7 following the decision criteria from the tables 8a through 8d for the two groups of selected participants (HQL+ and HQL~) and the group of remaining participants.

Table 9

Summary of the Groups of Participants for the Qualitative Data Analysis

P	*Focus homework*			*Difficult subject matter*			
	Place - quiet	**Interest**	**Duration**	**Sense - interest**	**Extra - basics**	**OK mark**	**More time**
HQL+							
1		+		+	Ex		
5	+						
8	+			+			
11	+			+		+	
24			+	+			+
26	+					+	
HQL~							
12				+	Ex		
13			+			+	
18			+				
21	+			-			

3		-					+
25	+						
				+	Ex		
Q II/IV							
2			+				
4				+			
7			+				+/-
14	+						
16					Ex		
17					Ex		
27							+

Note. HQL+ = Higher-Quality Learning + inter-individual group based on overall quadrant analysis (see Table 8). HQL~ = Higher-Quality Learning +/- inter-individual group. Q II/IV = remaining inter-individual group from the quadrants II and IV.

The results of Table 9 show the main differences regarding the participants' position on the homework-learning situation per identified inter-individual group and the remaining group of participants. Importantly, the identification of the inter-individual groups was possible because of the final analysis' connections made with the qualitative data. The first identified inter-individual group was labeled Higher-Quality Learning High (HQL+) and it was positioned mainly in Quadrant I, in that the qualitative data highlighted this group's emphasis on focusing on a specific and quiet place to do homework and to learn difficult subject matter by making sense of and obtaining a thorough understanding of (interested) subject matter. It is this focus that provides for conditional information because it explains the existence of the HQL+ group. The second inter-individual group, labeled Higher-Quality Learning Sometimes (HQL~), was positioned mainly in Quadrant III, in that the qualitative data highlighted

this group's emphasis on spending time on doing homework and focusing on doing extra practice tasks for difficult subject matter. The four rectangular frameworks in Table 9 show how the group HQL+ differs from the other groups regarding their views on and interpretations of homework learning. Notably, because only the responses of two open-ended questions were analyzed qualitatively for this illustrative example, not every participant's position is present in Table 9.

To conclude, if the data had been collected to identify conditional information in homework-learning situations, and the complete data analysis were performed and presented, then the results in Table 9 can be interpreted as follows. In line with the theoretical framework of Figure 2, to the degree of emphasizing a quiet place to learn and tackling difficult subject matter by focusing on understanding and making sense of it, the HQL+ participants differ from the remaining participants and form an inter-individual group regarding homework learning in general. The remaining participants' focus is on the duration of learning in terms of learning for a longer period of time than usual and doing extra practice learning tasks.

Discussion

Due to the aforementioned limitation of the data employed in the data analysis of the data not being collected to include timescales, context, and circumstances (see Figure 2), this illustrative example can present only how to employ the four-quadrant relationship data-analytical technique and provide for a preliminary overview of its possibilities and challenges. Hence, the aim of this discussion is to offer information about the four-quadrant relationship data-analytical technique in comparison to and in addition to other data-analytical techniques to establish groups and conditional information.

There are various standard statistical data-analytical techniques to identify inter-individual groups, especially, the multivariate techniques of clustering and analysis of variance (MANOVA) in conjunction with analysis of covariance (MANCOVA). Cluster analysis can identify mutually exclusive inter-individual groups by defining groups via the maximum homogeneity among the characteristics. Cluster analysis is exploratory, in that it classifies and categorizes the profiles of participants as they exist in the groups in the sample rather than working with either predefined groups, such as in multivariate discriminant analysis, and predefined dependent metric variables, such as in MANOVA. Both, discriminant analysis and MANOVA assess the differences between groups via the means of multiple variables as they are specified by the researcher, however, MANOVA uses multiple metric variables as the dependent variable (i.e., based on non-metric variables) to specify groups that exhibit differences on the set of dependent variables. Conversely, discriminant analysis uses a single non-metric dependent variable based on several metric independent variables that form a linear combination to discriminate best between a priori defined groups. Therefore, although all three data-analytical techniques are sensitive to outliers and restricted to predefined variables, it is in cluster analysis that the researcher specifies the linear combination of variables via their weights, and it is in discriminant analysis and MANOVA that the weights of the linear combination of variables are estimated empirically.

However, the rich variety of information and the diverse patterns of change that are found especially in research regarding individual person's processes and behavior has led to research (Arocha, 2021; Van Geert & Van Dijk, 2021) on the assessment of

intra-individual variability beyond the standard statistical techniques, such as the data-analytical techniques of complex dynamic systems for high-frequency observation of authentic behavior. The challenges for complex dynamic system data analysis lies in obtaining a connection between the individual differences on the one hand, which are often dynamic, and the mechanistic explanations that goes beyond the individual, on the other hand. Also, the standard statistical data-analytical techniques face similar challenges when the mean is used to identify inter-individual groups, that is, via a general overview of the data, where the complexity and dynamics of the (time series) intra-individual data require a more single-individual analysis to obtain a better understanding of *why* some individuals belong to certain inter-individual groups. For example, Molenaar and Lawrence (2012) proposed dynamic factor analysis for the data analysis of intra-individual variation that is obtained via time-series designs rather than an analysis of inter-individual variation because, they argued, pooling across participants (e.g., via ANOVA, factor analysis, and regression analysis) does not provide for valid information on developmental processes.

Although all standard statistics assume that inter-individual information could lead to generalized information about (sub-) populations (i.e., the ergodic assumption), its requirements of assuming a stationary or constant mean in the Gaussian process *and* invariance across participants (i.e., each participant following the same dynamic developmental model) is not in agreement with the actual developmental process of individuals that have time varying means. In other words, standard statistical inter-individual development does not have to agree with intra-individual development and, consequently, a data-analytical technique as factor analysis is insensitive to the heterogeneity in populations, as Molenaar et al. (2009) found via simulations of data. Instead, Molenaar et al. (2012) proposed dynamic factor analysis to analyze intra-individual variation that is stationary in time, but without all participants having to obey the same statistical model. This requires a factor analysis of single-participant multivariate time-series data. The research of Molenaar et al. (2009) showed that dynamic factor analysis of several participants separately yielded interesting features of dynamic behavior. Another advantage of factor analysis for single-participant multi-variate time-series data analysis is that it enables the discovery of latent variables (i.e., variables that have shared variance) in the observed data. The limitations are that the factor analysis cannot include qualitative data and it is difficult to compare participants.

Another issue regarding the data analysis of complex and dynamic intra-individual observed information is that the data analysis remains restricted to the variables that the researcher is interested in rather than enabling the discovery of the interrelatedness between variables to identify the structure of correlations between the variables. For example, Ram et al. (2012) studied the alternative possibilities of structural equation modeling (SEM) via longitudinal mixture models (i.e., multi-group structural equation models, such as latent class growth model) to acknowledge the heterogeneity or individuality of participants in data analysis and existent interrelated structures between variables without stating a priori a specific latent variable model. Although the exploratory nature of SEM-related models offer possibilities to identify sub-groups of individuals in samples, if employed without the constraints of selecting a model, it also involves the limitations of (a) only being useful to articulate theoretical hypotheses and (b) allowing to find only those results that were looked for because the chosen model implicitly or explicitly produces certain archetypes or kinds of features and patterns.

Similarly, Borsboom et al. (2021) argued in favor of network model or system analysis for multivariate data to focus on the structure of relationships between individual participants and the pairwise patterns of conditional dependencies between the variables that are present in the data. Network models consist of a construction of nodes and links in a network to represent the structural and dynamical features of, for instance, behavior (e.g., social networks) and phenomena (e.g., neural networks). Edge weights are used typically to describe the connection between two nodes. Although network model data analysis can be viewed as an extension of SEM, but with the advantage of being unidirectional, it also has as a limitation that edges are estimated rather than observed. As a consequence, it can be difficult to interpret individual edges because information about its significance is described insufficiently, and the centrality of variables can point to different kinds of information (e.g., closeness, eigenvalue and expected influence, and degree of strength). Additionally, (a) if important nodes are missing, then this will influence the network architecture and (b) if interactions occur at different timescales, then this can complicate the network structure (i.e., the central and peripheral place of certain nodes in the network can vary). Therefore, network model data analysis may not always be insightful if it cannot be narrowed down to sparse network structures.

To summarize, researchers are exploring different and new kinds of data-analytical techniques to study actual-world observations that involve complex and dynamic information, one of which is the research subject of situations and persons and the conditional information that can provide for a stipulation regarding their behavior. To support data analysis for research subjects that involve complex and dynamic actual-world observations, because these data often show disorder and can involve both latent and emerging variables, visualizations are helpful for the purpose of getting a grip of the data. The four-quadrant relationship data analysis has the advantage of enabling an initial exploration and understanding of the data without the restrictions of the aforementioned mean, estimating (i.e., either empirically or established by the researcher), and the neglecting of emerging variables, because these components that belong to most standard statistical techniques can produce inter-individual groups based on insufficient information and finding what one is looking for. Another advantage of four-quadrant relationship data analysis for initial data exploration and understanding is that the researcher can examine not only single individual information in relation to multiple other single individuals' information, but also the connections between different kinds of data and emerging variables.

To conclude, the aim of this illustrate example was to present the four-quadrant relationship data-analytical technique for exploring conditional information in complex and dynamic data regarding situation and persons. The data analysis showed that the qualitative data were essential for identifying inter-individual groups and conditional information. The four-quadrant data-analysis technique enabled the identification of inter-individual groups based on the person-specific intra-individual quantitative and quantitized data together and then adding the qualitative data. The quantitized data that provided for overall and similar responses from most participants were interpreted as initial conditions. The inter-individual group-specific features were interpreted as conditional information because it provided for a stipulation that explained the homework-learning situation. More research is needed to substantiate the results found in this illustrative example.

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Appendix A: The Questions on Learning in General

1. The manner of homework learning in general

a. I always learn in the same manner because learning is easy for me.
b. I consider in advance which learning technique to use because I have to put effort into learning.
c. I always learn in the same manner because I find a passing mark good enough.
d. I consider in advance which learning technique to use because I want high marks.

2. The impact of marks on homework learning

a. If I do not receive a passing mark, then I think "Too bad, next time better" or I will learn for a longer period of time.
b. If I receive a mark, either a passing or a not passing mark, I will always reconsider how to improve my learning.
c. If I do not receive a passing mark, then next time I always will do better by learning for a longer period of time.
d. I always receive good marks and do not have to think about how to improve my learning.

3. The kinds of learning features that are focused on during homework

a. When I learn at home, I can concentrate completely.
b. When I learn at home, I try to work as quickly as possible because I do not want to spend much time on learning (there are other things I also want to do).
c. When I learn at home, I can memorize it all rather quickly.
d. when I learn at home, I simultaneously consider if the learning technique I am using requires improvements.

4. The manner of homework learning when learning tasks are complex or extra difficult

a. If the subject matter is difficult, then most of the time I can memorize it is easily.
b. If the subject matter is difficult, then I will put in extra time.
c. If the subject matter is difficult, then I do the practice tasks precisely to be able to do that which is required minimally.
d. If the subject matter is difficult, then I will study until I understand it completely.

Author Note

Joke H. van Velzen, Research Institute of Child Development and Education, University of Amsterdam. Correspondence concerning this article should be addressed to Joke van Velzen, e-mail: j.h.vanvelzen@sigmetack.com.

Conflict of Interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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