Title: Coding and Counting – Frequency Analysis for Group Research

Preface

The basic idea of this chapter is to provide an introduction to the design and conduct of frequency analysis for group research. Frequency analysis has been commonly used for decades in several disciplines and fields of research as stand alone procedures (e.g., configural frequency analysis in clinical psychology, Lienert, 1971). But, despite of specialised articles in experimental psychology journals (e.g., Wickens, 1993), the description of frequency analysis as a specific method within group studies (e.g., coding group interaction data like chat protocols, then calculating frequencies across categories) is rare. This is remarkable, because the interests in frequency analysis nowadays have moved towards to the procedures of implementing its results as indices for further analysis, e.g. for the investigation of relationships between group processes like collaboration and outputs like performance by using the results of frequency analysis as inputs in inferential statistics. In this vein, this chapter attempts to highlight the most important options to use frequency analysis in group research as a relevant brick to gap the bridge between qualitative and quantitative methods (mixed method research). Furthermore, we fold into our descriptions and discussions empirical examples to illustrate the prerequisites, requirements and consequences of using frequency analysis in the field of group research. Finally, we clarify ways to present the results of frequency analysis for analyzing group data.

1. Frequency Analysis as Starting Point for Mixed Method Research

Many research designs in experimental psychology and especially studies that investigate group interactions in the field generate data that are fundamentally discrete or categorical in nature. For instance, occurrences of behaviors like specific words or statements in group discussions are analyzed, and produce tables of frequencies. Despite an extensive and accessible literature on the topic in the area of astrophysics (e.g., Lomb, 1976) or cryptology (e.g., the study of the frequency of letters or groups of letters in a ciphertext, Peng & Hengartner, 2002), frequency analysis is common for group researchers but rarely described as a specific method in experimental psychology. This is remarkable, because in other areas of scientific psychological research, frequency analysis has repeatedly been described as a specific procedure. In clinical psychology for example, one prominent technique is the configural frequency analysis (CFA) as a method of exploratory data analysis, introduced by Lienert (1971). The main goal of this CFA is to detect patterns in the data that occur significantly more (types) or significantly less (antitypes) frequent than expected by chance. The basic idea of CFA is to provide (by the identified frequencies) insights into the structure of data. In this vein, types are interpreted as concepts which are constituted by a pattern of variable values that generally occur together. In contrast, antitypes are interpreted as patterns of variable values that do in general not occur together (e.g., Eye, 2002).
In sum, frequency analysis is used in clinical psychology (e.g., CFA) but has been rarely described independent from concrete studies as a specific *method* in psychology,

especially in group research. In general, the preoccupation with categorial frequency data is not new for group research, especially in the social science literature. Many authors like Goodman (1971), Bishop, Fienberg, and Holland (1975) or Haberman (1978) discuss the importance and chances of using frequency data in research. But, despite of specialised articles in experimental psychology journals (e.g., Olzak & Wickens, 1983; Wickens, 1993), the specific description frequency analysis as a specific method within group studies is rare. As stated by Vokey (2003), there are different reasons for this fact: one reason may be the general form of exposition in the statistical literature like handbooks, with emphases and concerns on a very theoretical or methodological level far removed from the practical aspects of the typical experimental psychologist or group research. Another reason for this fact may be that most books on statistical methods for psychologists and group researchers have no mention of the specific usage of frequency analysis. The relevant aspects and the computational techniques for frequency data are appropriate for contingency tables that are analysed with the goodness-of-fit approach (tests of independence) developed early in the history of statistics (Pearson, 1916). Furthermore, most presentations routinely are concerned with correlational rather than experimental and population-based designs (i.e., random-sampling). Hence, experimental group research was not the main focus of frequency analysis in the past. But what is frequency analysis in the area of group research? In the following chapter, we will focus on answering this question.

1.1 Frequency Analysis in Group Research - Empirical Examples

In the different areas of group research, qualitative coding systems are a potential starting point for frequency analysis. For example, the Co-ACT coding system (Kolbe, Burtscher, & Manser, 2013) for observing coordination behavior in acute care teams like health care teams in high-risk, dynamic disciplines such as emergency medicine, surgery, and anesthesia, investigates and codes specific teamwork behaviors in action teams. By doing so, the team behaviors are structured in the four quadrants “explicit action coordination”, “implicit action coordination”, “explicit information coordination”, and “implicit information coordination” (for further information, see Kolbe in this book). After the coding procedure, frequency analysis may be used to analyze the occurrence and timing of coordination behavior, thus providing the basis for a detailed understanding of team interaction. Another example is the TRAWIS system for coding transactive knowledge and knowledge exchange (Brauner, 2006; for further information see Brauner in this book). By coding two basic dimensions of knowledge that can be addressed in verbal communication ((1) object-level knowledge or meta-level knowledge; (2) personal knowledge or social knowledge), frequency analysis may be used to analyze the occurrence of differences in transactive knowledge acquisition between types of teams or differences in knowledge acquisition between types of communication (e.g. face-to-face vs. computer-mediated).
Transferring these empirical examples to a more general level, frequency analysis could be described here as a process that breaks down complex behaviors into smaller units and counts their occurrence. By counting the occurrences of behaviors in a specific context or data set (e.g., in a group discussion), frequency analysis tries to predict future

occurrences. By doing so, qualitative (e.g., behavior coding) and quantitative research procedures (e.g. counting or quantifying behaviour categories for inferential statistics) are combined. Hence, frequency analysis could be defined as a relevant brick to gap the bridge between qualitative and quantitative methods in mixed method research.

1.2 Frequency Analysis in Group Research - Methodological Aspects: Research Designs and Samples, Data Integration, and Researcher's Skills

As described above, coding systems are commonly used for frequency analysis on an empirical level. What does this combination of qualitative coding systems and quantitative frequency analysis mean on a methodological level?
Transferred to methodological considerations, frequency analysis is used as a starting point for mixed methods research. Several definitions of mixed methods have emerged over the last years and decades that incorporate different elements of methods, research perspectives, philosophies and research designs (e.g., Johnson, Onwuegbuzie, & Turner, 2007). In this vein, Cresswell and Plano Clark (2011, p. 5) rely on a definition of core characteristics of mixed method research that highlights the key components of designing and conducting an empirical mixed methods study:

> *"In mixed methods, the researcher a) collects and analyzes persuasively and rigorously both qualitative and quantitative data (based on research questions), b) mixes (or integrates or links) the two forms of data concurrently by combining them (or merging them), sequentially by having one build on the other, or embedding one within the other, c) gives priority to one or to both forms of data (in terms of what the research emphasizes), d) uses the procedures in a single study or in multiple phases of a program of study, e) frames these procedures within philosophical worldviews and theoretical lenses, and f) combines the procedures into specific research designs that direct the plan for conducting the study."*

On an overall level, these core characteristics determine how researchers can integrate quantitative and qualitative methods in empirical studies. Regarding frequency analysis, these core characteristics not only affect how an empirical study is designed and conducted, they also affect how frequency analyses are used in research: 1) either as stand alone procedure or 2) as a basis or indices for further analysis. To understand the basic idea of using frequency analysis in the nature of mixed methods research, different **research designs** should be focussed. Regarding Creswell, Plano Clark, and Garrett (2008), different research designs could be developed to conduct mixed methods research. The most prominent differentiation is to distinguish between a triangulation design and a concurrent embedded design. On the one hand, the triangulation design is a one-phase design in which quantitative and/or qualitative data are collected and analyzed in parallel and separately and then - after the study is finished - merged together to compare or interpret results. On the other hand, researchers use the second type, the embedded design, when they want to enhance a study based on one method by including a secondary dataset from another method (Creswell et al., 2008, p. 68). In

this case, the qualitative data are collected concurrently. Transferred to frequency analysis, in case 1 (triangulation) the results of a frequency analysis are interpreted separately or as stand alone results. In case 2 (embedded design), the results of the frequency analysis could be used as basis for further quantitative analysis. In this case, issues of data integration and different sequential mixed method designs like an explanatory or an exploratory design are relevant to combine qualitative and quantitative data.

Regarding **data integration**, Bryman (2008) states that it can be challenging to integrate two sets of different forms of data and their results in a meaningful way. Erzberger and Kelle (2003) offer some guidelines on the integration of two strands of data: (1) designing and implementing comparable topics or questions for both arms (e.g., quantitative and qualitative strands of the study address the same questions or concepts), (2) converting the data so that it can more easily compared, and (3) using matrices to organize both sets of data into one table. Regarding the second strategy, it is more intuitive for researchers to quantify qualitative data by transformation than to transform quantitative into qualitative data. This second strategy is most relevant for frequency analysis and the idea of using the frequencies as a starting point for further quantitative analysis. For example, Witcher and colleagues (2001) transformed their qualitative data into quantitative results by counting themes and calculating frequencies. In this way, the authors determined which themes or topics were mentioned more frequently in their study. Based on a similar strategy, Crone and Teddlie (1995) carry this procedure a step further by quantifying qualitative themes and then conducting statistical analyses on these data sets. These researchers gathered data from teachers and administrators and then computed chi square tests in order to compare data from schools with varying levels of effectiveness (see also Cresswell et al., 2008, p. 73).

Besides data integration, researchers need to consider the consequences of having **different samples** when merging the results of a frequency analysis based on qualitative codings with quantitative datasets (Creswell et, 2008). This is important because qualitative and quantitative data are usually collected for different purposes, with different issues, different quality standards and different sample sizes. On the one hand, it could be a strategy to use same individuals in both data sets to compare results in a specific way. On the other hand, it could be useful to use different individuals and different sample sizes. For example, for analyzing group interaction data it could be adequate to analyze some selected groups with qualitative coding schemes “in depth”. In this case, a smaller sample size would be the consequence. In the same study, it could be interesting to collect large quantitative datasets to generalize the results. Hence, it could be a proper strategy to have unequal sample sizes in qualitative and quantitative strands for the purpose of providing a full picture of the situation (for an example of unequal sample sizes, see Hendrix et al., 2001).

Last but not least, the usage of the results of frequency analysis as basis for further analysis depends on the **researcher’s skills** to conduct mixed methods research (Creswell & Plano Clark, 2011, p. 79). As a prerequisite, the researcher needs expertise in applying both qualitative and quantitative methods or it could be necessary to combine several individual expertises to a collaborative research environment. Without combining expertise in both quantitative and qualitative methods, there is the risk that researchers use either quantitative or qualitative methods in a suboptimal way rather

than than combining them (Weitzman & Levkoff, 2000). Hence, a combination of skills is appropriate to use the results of frequency analysis as basis for further quantitative analysis.

2. Procedures of Frequency Analysis in Group Research

The chapter 2.1 presents options for the reporting of the results of frequency analysis. It will explain that depicting simple descriptive frequencies is not the only option to report the results of frequency analysis. Before reporting results, it should be considered that the way the data have been collected affects what statistics may be used or how the results will be reported. For example, many statistical procedures make assumptions about the distribution of the variable being analyzed (e.g., normal distribution vs. nonlinear transformations, Hair et al., 1998). Additionally, it is important to consider if the design of a study tries to generate research questions and/or hypothesis (e.g., an explorative design) or if the design tries to test hypotheses. Subsequently, statistical tests of significance could be categorized according to the number of analyzed variables (e.g., bivariate: one independent, and one dependent variable; multivariate: more than two variables). Transferred to frequency analysis, this means that the researcher needs to decide how the data could be handled: The researcher has to select the appropriate statistical test and - on a more general level - the researcher has to decide how the results of a frequency analysis are used: as stand alone results (chapter 2.1, chapter 2.2) or as basis for indices and variables for further analysis (chapter 2.3). In this latter case, the results of frequency analyses are used as indices and variables for further multivariate analyses (cf., Neuendorf, 2002, p. 167).

2.1 Reporting frequencies as stand alone results - numeric frequencies, pie charts and bar graphs

Neuendorf (2002, p. 172) proposed different manners to report the results of frequencies: (1) **numeric frequencies**, (2) **pie charts**, and (3) **bar graphs**. In general, **numeric frequencies** show the occurrence of specific data (e.g., the frequency of different codes of a coding scheme). By doing so, these findings can answer research questions such as “What are the frequencies of sexual behaviors (physical, implied, and verbal) and their consequences as depicted on daytime soap operas?” (Neuendorf, 2002, p. 172 based on Olson, 1994). Usually, no further hypotheses are being tested, and no tests of statistical significance are used. Here, frequencies are used as stand alone results. To go a step further, one-sample z-tests are used to test if the frequency of a code (e.g., a specific behavior) is significantly larger than zero. Furthermore, bivariate tests could be used to analyze the relationship between different frequencies. In this regard, contingency tables are types of tables in a matrix format that display the frequency distribution of codes or variables. These tables allow to see the proportions of different variables in a sample (e.g., the occurrence of men or women in a sample). The significance of the difference between the two proportions can by analyzed with different statistical tests including Pearson’s chi-squared test, the G-Test, Fisher’s exact test, and

the Barnard's test. If the proportions of frequencies in the different columns vary significantly between rows, a contingency between the two variables is identified. In other words, the variables/frequencies are not independent. If there is no contingency, the two variables are independent.
Table x1 shows the simple contingency table with only two levels also called 2x2 contingency table. This example originates from a study investigating the influences of type of provided personal territories (e.g., individual tablets) on the participants territorial behavior in the group territory (interactive tabletop). The participants worked in this experiment in dyads at a large tabletop on a brainstorming task. The territorial behavior was observed based on the videotaped experiments and coded as follows. A group exhibits territorial behavior when at least one participant places their notes on the tabletop in the area in front of them. By counting the occurrence of the territorial behavior it becomes evident that all groups deprived of personal territories created personal territories in their group territories. Meanwhile, most groups in the territorial conditions (fix, dynamic, mobile) solved the brainstorming task without creating additional personal territories.

Table x1. 2x4 contingency table

Territorial behavior	Territory			
	non-territorial	fix	dynamic	mobile
no personal territories built	0	5	6	6
personal territories	10	6	4	3

Another option to report frequencies as stand alone results are (2) **frequency pie charts**. Figure x1 shows the same information as Table x1 in as a pie chart format. In this case, the preponderance of codes are visually displayed in a pie-slice format. In general, no statistical tests are employed and no hypotheses are addressed by this descriptive version of findings.

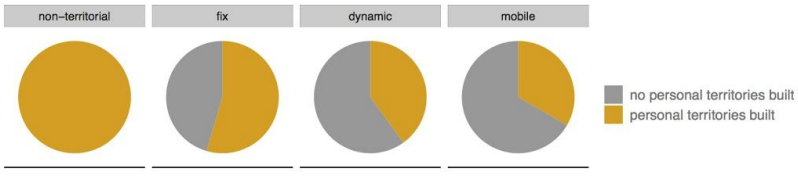


Figure x1. **Frequency pie chart** *created with R package ggplot2 (Wickham,2006)*

An additional option for presenting basic frequencies are (3) **bar graphs.** Figure x3 displays the same information as Table x1 and Figure x1.

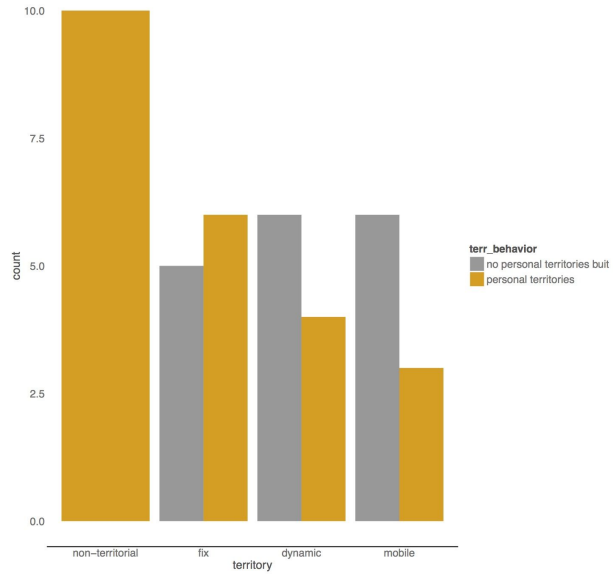


Figure x2. ***Bar graph*** *created with R package ggplot2 (Wickham,2006)*

Overall, the explained visual presentations can help to report and interpret the results of frequency analyses. But besides these typical options for presenting frequencies, some more specific options are relevant to report frequencies as results in group research. For instance, log files and density plots are described in the following chapter.

2.2 Reporting frequencies in Group Research: From Log Files to Density Plots

As stated above, the results of frequency analysis could be reported as bar graphs, pie charts, and frequency pie charts. Besides this rather "traditional" way of reporting results, other (sometimes more adequate options) for the report of group interaction data are available. In the following, different empirical examples are described to present the results of frequency analysis in group research. Example 1 shows a temporal mapping of the data (when did a certain behavior occurred during group interaction) and example 2 a spatial mapping (where did the the behavior occurred during the interaction). Both the temporal and the spatial mapping can be combined with visualisation of the propensity of the visualized behavior and/or of the entity performing that behavior.

Example 1: In an experiment, participants received the task to use a floor plan of a future office to furnish a flexible office and create different working zones (e.g.,"silent zones" for concentrated individual office work or "social zones" for informal meetings and mutual social exchange among colleagues). Study participants worked at an interactive tabletop in dyads for 45 minutes in two conditions (experimental and control). The experimental condition offered the tabletop with full interactive functions (such as drawing zones, dragging and placing furniture pieces on the floor plan) whereas the control condition offered the same interface with reduced functionality. The participants interactions were videotaped and all videos were subsequently analysed by coding for

different types of group behaviors, e.g. type of action with the interface (zoning the office or furnishing), occurrence of epistemic actions and deixis during zoning and furnishing. Epistemic actions are defined as “external actions that an agent performs in order to change his or her own [mental] computational state” (Kirsh, & Maglios, 1994 p. 514). Deixis are defined as communicative gestures with deitic reference, i.e. pointing to something while communicating about it. All videos were segmented with a ten seconds interval and the occurrence of the two behaviors was coded for each interval. To insure reliability a second independent coder coded 10% of the videos.
Figure x3 shows the results for two groups per condition by mapping groups’ behavior to the timeline of the experiment. Such analysis and their visualisations make evident not only how often a behavior occurred but also the moment of occurrence and co-occurring behaviors. For example all groups had disjoint episodes of zoning and furnishing with the exception of group 1 in the the control condition who started by zoning, moved to furnishing and then in the last minutes of the experiment made significant changes both to the zones as well as to the furnishing arrangements. Meanwhile group 8 started by zoning and after that furnished the rooms and only minimally changed to the zones. Such a graph makes not only the co-occurrence of behaviors salient but also the lack thereof. For example, in the experimental condition, group 8 made use of epistemic action most of the time, meanwhile group 21 only used them during the zoning phase. Meanwhile all groups communicated using deixis most of the time. The amount of interaction is shown by the density of that behavior (number of lines per unit of time).

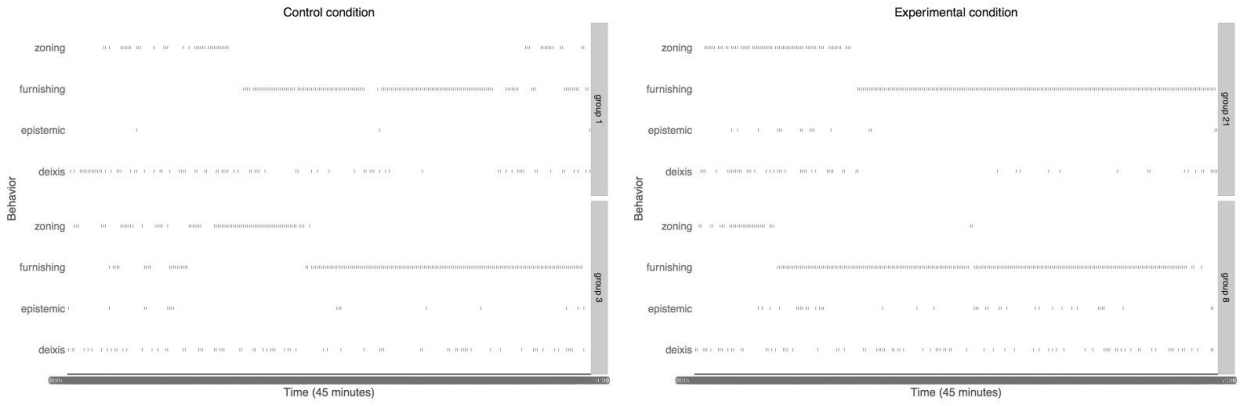


Figure x3 Visualisation of behavior on time axes, *created with R package ggplot2 (Wickham,2006)*

Example 2: In another experiment, participants brainstormed ideas for a flexible office at an interactive tabletop (the task was similar to the task in example 1, but rather than designing the office with the help of a floorplan participants were asked to develop ideas and write them down in notes, then choosing their best ideas). The participants were seated at the beginning of the experiment at the long sides of a tabletop (group space), but were free to move during the experiment. Each participant received a tablet as their “personal space”, which they could use in different ways depending on the condition

they were assigned to. Four conditions of “personal spaces” were contrasted: “fix” (the tablet could not be moved, but could additionally be used to brainstorm), “dynamic” (the tablet had the same function as in the fix condition, but could also be moved around the table) and “mobile” (the tablet had the same function as in the fix condition, but could be used anywhere in the room), “non-territorial” (the tablet was used only to read the task and fill out questionnaires - this was a control condition). All groups were videotaped and log files of the interactions with the tabletop interface were recorded. The synchronized video with the log files were used to code which person completed each interaction. Figures x4 to x6 show the *spatial mapping* of same data in different manners.The figures differ by the way they represent the behavior of interest (in this case interaction with the tabletop application) spatial mapping (where did the behavior occurred), amount (how high is the propensity of that behavior) and entity mapping (who performed that behavior).
Figure x4 shows an activity plot mapping the place where the interactions took place on the tabletop regardless who performed that interaction for all coded groups in the four conditions. A density plot was added to the visualisation to make more evident where most interactions were performed. This figure was created with the open source program R Cran, package hdrcde (Hyndman, Einbeck & Wand, 2009)

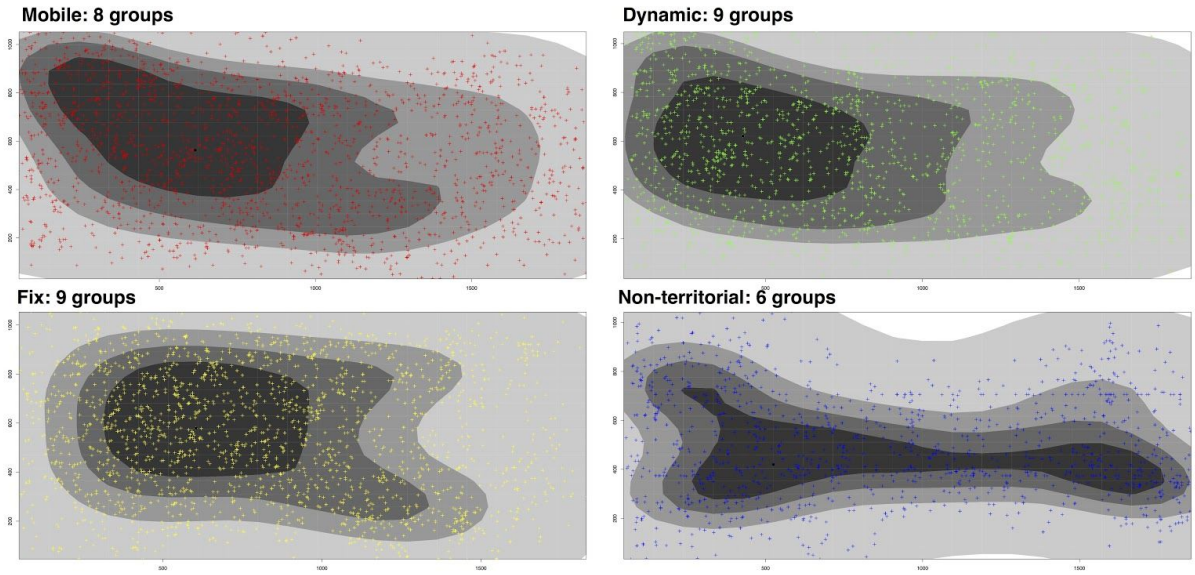


Figure x4. Density plot of the interaction on the tabletop created with package hdrcde (Hyndman,Einbeck & Wand, 2009)

In Figure x5, the participants’ interaction with the interface was mapped on the tabletop whereby the different colors of the points differentiated between the person who performed the interaction (participant 1 in red, and participant 2 in blue). Two horizontal lines partition the table surface in 3 equal zones. The visualisation makes apparent that the participants in the mobile condition used the tabletop in more democratic way, performing interaction on most surface of the interactive tabletop. Meanwhile in the non-territorial condition, the participants created some kind of a personal space in front

of them and interacted more in the nearest ⅓ of the tabletop and the middle and less in the ⅓ of the table that was further away from them.

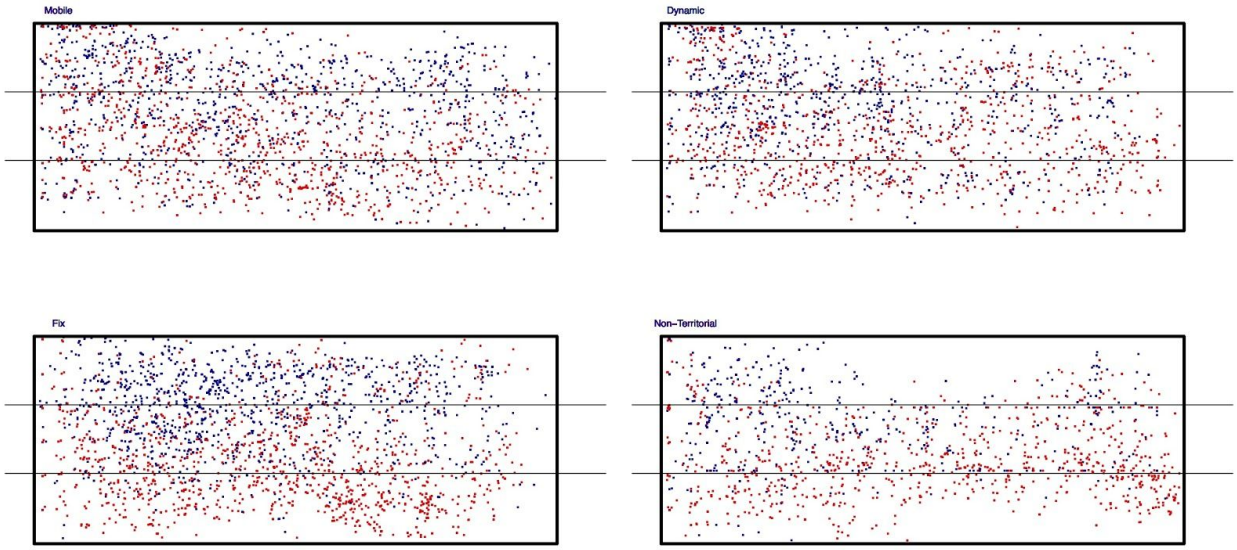
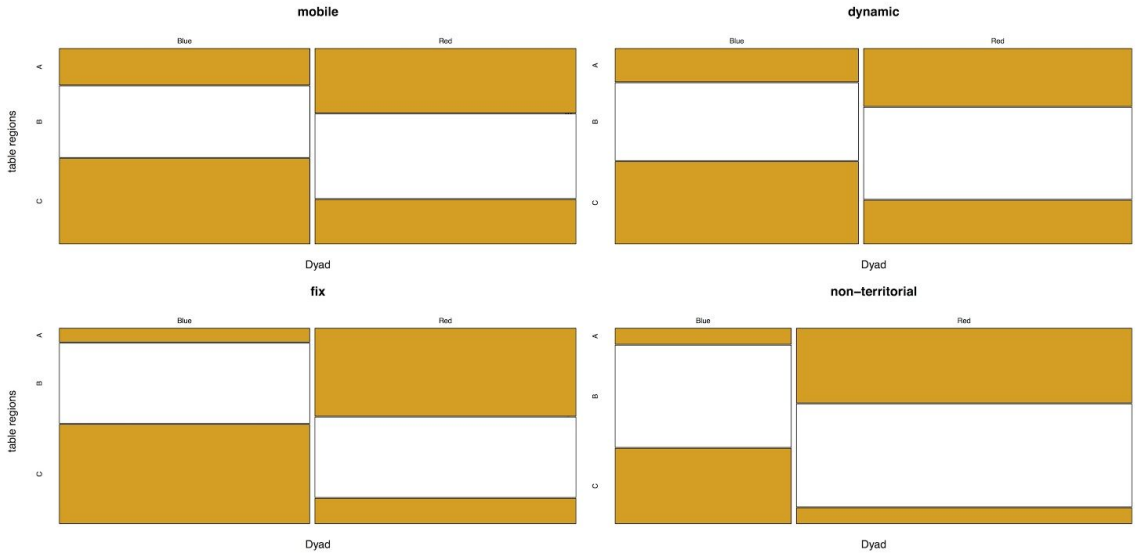


Figure x5 Visualisation of the interaction on the tabletop, one participant coded with red and the other one with blue *created with R package ggplot2 (Wickham, 2006)*.

Figure x6 focuses on the amount of interaction. Only a crude mapping to the tabletop surface is made in this visualisation: the tabletop is partitioned in three equal areas on the tabletop A, B and C. Differences in the amount of interaction between participants (Blu = participant 1, Red = participant 2, same colors as in the other visualisations) in the four conditions become apparent. The mobile and dynamic conditions the participants used most of the tabletop surface. Meanwhile in the fix and non-territorial condition the participants interacted with the notes mostly in the middle area (white) and in area next to them.



Region size shows the amount of interaction in a table region by a person. The table was divided in 3 geometrically equal sizes

Figure x6 Visualisation of the amount of interaction on the tabletop. The tabletop was partitioned in the 3 equal sized areas (A, B and C). The interaction of the two participants is shown in two columns (Red = participant 1/ Blue = participant 2) ***created with graphics (R Core Team, 2015)***

2.3 Beyond Descriptive Metrics - Frequencies as Indices and Further Analysis

As stated above, the researcher has to decide how the results of a frequency analysis are used: as stand alone results (chapter 2.1, chapter 2.2) or as a basis for further indices and variables. In this case, the results of frequency analyses are used as indices and variables for further multivariate analyses (cf., Neuendorf, 2002, p. 167). Why is this important, and what are the advantages of this procedure?

The visualizations and reportings of descriptive metrics like frequencies are necessary but - in most of the cases - not sufficient to understand fully complex aspects of group interaction behavior or relationships on a more general level (e.g., groups and network perspective, Contractor & Su, 2011). For instance, the reporting of descriptive frequencies as discussed above can provide insight in the occurrence of specific behaviors in group discussions, but it does not provide insights into the relationship between these behaviors and specific outputs of the group interaction (e.g., group performance). Hence, the use of frequency analysis as a stand alone procedure or result could not be defined as a statistically defensible measure of whether the observed behaviors have different effects on outcomes of group work. This is the reason why frequencies are often used as a basis for inferential statistics by calculating indices for further analysis. This aspect is specifically relevant for group research, because many studies postulate theoretical and empirical relationships (e.g., empirical input-process-output models, Rack, Ellwart, Hertel & Konradt, 2011) between inputs (e.g. group size, individual motivation of group members), processes (e.g., information sharing), and outcomes (e.g., group performance). Then frequency analysis provides a

solid basis for more complex data analysis with inferential statistics like regressions analysis or - especially relevant for group research - multilevel modeling (e.g., Kashy & Hagiwara, 2011; Walter & Rack, 2010). To explain the procedures of using frequency analysis as basis for indices that result in quantitative measures to assess the impact of a treatment on an outcome, the following procedure exemplifies how frequencies can be turned into process quality indicators (here: collaboration index) and then related to outcome (here: learning success).

Example 3: In an experimental study on group learning in digital learning environments, two types of using a web-based video collaboration tool (WebDiver, see http://diver.stanford.edu/) for distinct learning activities were compared: learning by a design task *vs.* learning by a discussion task (e.g., Zahn et al., 2009). Based on a theoretical distinction between design and discussion *for learning* dyadic interaction data from a sample of 69 students were collected. The data consisted of written communication in a chat tool and comments written into the video collaboration tool. From these raw data, the quality of the dyadic interactions was analyzed by coding (a) frequencies of content aspects that related directly to the learning goal and (b) aspects of collaboration quality. Two coding schemes were developed. The first one – Coding Scheme I – was developed to assess the contents of the written comments. The second one – Coding Scheme II – was developed to assess the overall quality of interactions within dyads from the chats (computer-mediated communication) based on the contents of the learners`utterances. For Coding Scheme I, screen videos were viewed in addition to determine which comment was written by which collaboration partner, thereby counting the frequencies of comments created in partnership by both participants of the dyads *together* in contrast to frequencies of comments created by one of the partners *alone.* Coding Scheme II rating the communications within dyads further applied two subcategories: 1) frequencies of double reference as an indicator of collaboration in general, 2) frequencies of proposals for work structuring as an indicator of coordination activities, 3) frequencies of referencing one partner's utterances or directly addressing the other partner as an indicator for communication. The coding results were then integrated by weighting the category frequencies (e.g., number of utterances of category 1) by a factor of three),. to form a collaboration index. This collaboration index was used for further analyses on outcome effects (learning and knowledge acquisition).

3. Conclusion

In this chapter, we gave an introduction to the design and conduct of frequency analysis for group research. We offered descriptions of some of the most important options to use frequency analysis in a typical group research process as a relevant brick to gap the bridge between qualitative and quantitative methods. Furthermore, we fold into our descriptions and discussions empirical examples to illustrate the prerequisites, requirements and consequences of using frequency analysis in the field of group research. We continue to believe that frequency analysis is a reasonable way to investigate group interactions. Although this method could be used as stand alone

procedure, it is a notable option to generate behavior-related variables and indices for multivariate statistics to analyze specific relationships in small group research.

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