Tallinn University

School of Digital Technologies

# Software Tools for Supporting Literature Reviews: An Overview and a Case Study

Master Thesis

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# 1 Introduction

Conducting a methodological review of literature is an essential part of most academic endeavours (Levy & Ellis, 2006). In addition to helping create a firm foundation for advancing knowledge, it can aid researchers in understanding the state of art of the area being researched. Conducting a thorough literature review consists of multiple stages, in which suitable literature is identified, evaluated and interpreted.

Literature reviews are used to provide researchers with information on different fields of knowledge, but also to identify gaps in current research in order to suggest areas for further investigation (Kitchenham & Charters, 2007), hence they often serve as a starting point for many research projects. Conducting them thoroughly may be vital for the quality of the project. Undertaking a literature review is often seen by novice researchers as a trivial task, which leads many literature reviews to become simply an annotated bibliography (Hart, 1998). Writing a thorough literature review requires breadth, depth, clarity, among other characteristics.

Each set of literature review work methods can be categorised into a methodology or a set of guidelines. Although most methodologies share the same end goals, they may differ in terms of how data is gathered, analysed and synthesised (Grant & Booth, 2009). As stated by Grant & Booth (2009), these variations are most clearly evidenced in the structures and methodologies that distinguish review types from each other. Although the main stages of conducting literature reviews are similar in most methodologies (defining the research questions, browsing for relevant papers, excluding irrelevant papers etc.), the means in which these stages are carried out (the requirements and work methods) can differ.

As stated by Grant et. al. (2009), the amount of literature review methodologies present is vast, with more approaches constantly being defined. Most methodologies are defined on a theoretical basis, with researchers describing the methods that should be used and the contexts they should be applied in. The technological solutions that could assist researchers in conducting these literature reviews remain widely unspecified, which leaves most novice researchers with no information in regards to how information should be categorised and analysed.

Although researchers employ different literature reviewing approaches, most do so without describing their exact work methods in detail. The research problem is that the sequence of steps required to perform a certain type of literature review must often be derived from descriptions of

existing reviews. This can lead to confusion in regards to the exact work methods of different methodologies and which software can be used to support them.

The research goal, thus, is to describe different literature reviewing approaches by mapping them against the same framework, propose software that supports conducting literature reviews and to analyse how employing these tools improves the process of reviewing literature.

Using different applications and tools for conducting literature reviews may improve the quality of the research (Kashy, Thoennessen, Tsai, Davis, & Wolfe, 1997), but it can also hasten the entire process of carrying out a literature review. To aid researchers in identifying which tools to use with different work methods and methodologies, this thesis provides an overview of the various software that can support conducting literature reviews. To propose technological solutions, the requirements for carrying out different methodologies must be understood first. Hence, the thesis focuses on the following research questions:

- What are the different methodologies for conducting literature reviews?
- What are the different software tools that can be employed for conducting literature reviews?

In order to give an overview of how literature review methodologies could be supported by using different software solutions, an assessment is conducted of what requirements different methodologies enforce. For each requirement (e.g. text highlighting, tagging), a suitable tool is proposed. A hypothesis is put forth that using different tools for supporting different procedures of literature reviews will positively affect the process, thus improving the quality of the review.

To demonstrate the usage of the software proposed, an exemplary literature review is carried out. The methodology for the review is chosen from the ones described in the thesis and various technological solutions are used in all phases where possible. The literature review is written as a continuation of the work done by Shmorgun & Lamas (2015), who wrote a literature review of the research on the design of distributed user interfaces. The authors believed that this review would benefit from a more detailed reiteration, which is why this topic was chosen for the case study. Furthermore, the field of distributed user interfaces is still quite novel and the concepts in it have not been clearly defined yet, which makes it suitable for a literature review.

# 2 Literature reviews – definition and motivations

A literature review provides background on a certain area and details about previous research (Engage in Research, 2007). In addition to giving an account of what has been researched, a thorough literature review attempts to find conflicting views and deficits in existing papers, trying to explain where these discrepancies may originate from.

Reviewing what has been previously written on a topic before conducting research on it can be seen as a crucial endeavour for most academic projects (Webster & Watson, 2002). Carrying out a literature review can give researchers an overview of what has been done in a field of research previously. It can be seen as a thorough account of what has been published on a topic by accredited scholars and researchers (Taylor, 2009). A literature review must convey to the audience what has been established on a certain topic, what the strengths and weaknesses of the research are and which areas are in need of further improvement. This helps researchers avoid "reinventing the wheel" and find out what remains to be done in the field and build upon that foundation.

Working through existing material and sources allows researchers to place the relevance of their own research into a larger context of what has been already done, but it can also create a sense of rapport within the academic community. This may prove to be important to novice researchers, who have yet to build a reputation in the scientific community. By providing a thorough review of the topic, the audience will perceive the author as having done the necessary background studies.

The growing popularity of evidence-based research amongst different areas of knowledge lead to an increasing variety of review methodologies. Although these methodologies vary in terms of specific work methods, they all share the same base structure. Grant et. al. (2009) have defined this structure as the SALSA (Search, Appraisal, Synthesis and Analysis) framework.


*Figure 1: the SALSA framework stages with their corresponding results* (Grant & Booth, 2009)

The SALSA framework divides the literature review process into four stages. Each stage is represented in the literature review, but the exact work methods and the amount of sub-stages may differ for each literature reviewing methodology.

The searching stage aims to gather a large amount of publications by using a predefined search strategy (e.g. defining a list of search keywords, selecting the databases etc.). The aim of this stage is to define the research scope and preliminary list of publications to analyse.

The appraisal phase aims to evaluate all the papers that have been selected in the previous phase. The aim of this activity is to extract all irrelevant papers from the initial sample.

The final two phases deal with analysing the selected papers, drawing conclusions from them and categorising the findings by extracting relevant data from the papers collected. As a final stage, the findings are transcribed and summed up in a final report.

The results of the first stages of literature reviews are empirical studies that investigate a specific research question and are defined as *primary studies* (Kitchenham & Charters, 2007), while studies that review the primary studies with the aim of synthesising evidence related to a research question are defined as *secondary studies*.

Grant et. al. (2009) have described fourteen different primary reviewing methodologies, based on both scoping literary studies as well as personal experience. These methodologies were mapped against the SALSA framework and grouped into a table (see Figure 1), characterising each methodology by a short summary and the methods it uses for search, appraisal, synthesis and analysis.

To better understand what are the specific requirements of each methodology's different work phases, a new table was created based on Grant & Booth's (2009) table of methodologies, with each cell filled with specific work methods (see Appendix 1).

## 2.1 Systematic review

A systematic literature review is a well-defined literature reviewing methodology that aims to identify, analyse and interpret all available evidence related to a certain research question without being biased (Kitchenham & Charters, 2007). The reasons for conducting a systematic review can vary from the need to examine old theories to propose new ones to providing guidance to researchers planning future studies. As stated by Petticrew and Roberts (2006), a prominent use for systematic literature reviews is to methodically assess why different studies addressing the same question may have ended up with different results.

As stated by Kitchenham (2007), there are three main reasons for conducting a systematic review:

- To summarise existing information;
- To identify gaps in existing research;
- To provide a framework to appropriately position new research activities.

The main rationale for undertaking systematic literature reviews lies in their thoroughness. Although they require considerably more effort than many of their counterparts, a systematic review can provide researchers with thorough and fair analysis results, thus contributing to the eventual scientific value of the research.

The thoroughness of the methodology at hand is best seen when describing the SALSA stages - while most search, appraisal, synthesis and analysis phases may be summed up with a maximum of two work methods, a systematic review has widely been divided into three phases with each phase consisting of three to five sub phases, each with their own pre-defined work methods and requirements.

### 2.1.1 Search

Kitchenham and Charters (2007) have divided the systematic reviewing process into three different stages. By mapping these stages against the SALSA framework, the first stage (planning the review) and some sub-stages of the second stage (conducting the review) can be placed under the Search phase.

While many literature review methodologies begin with identifying the research question, a systematic review begins by identifying whether there is an actual need for a review. This phase can however be excluded, should the review be done for the researcher's own use (e.g. for a thesis). If previous reviews on similar subjects have been conducted, they should be evaluated by using predefined criteria. Kitchenham and Charters (2007) suggest using the checklist proposed by the Centre for Reviews and Dissemination, which dictates that each review should be checked for the title and background, research questions, authors, review methods, project timetable, dissemination strategy, support infrastructure, budget and reference (Tacconelli, 2010).

The document created by analysing existing reviews shall be used to solicit tenders from research groups that are willing to undertake the review, and it will also act as a steering document that helps to ensure that the review remains on topic.

This is followed up with defining the research question. Kitchenham (2007) states that this can be seen as the most important phase of the reviewing process. The research questions will drive the entire reviewing process - the primary studies must identify all studies relevant to the question; the appraisal phase must extract all data irrelevant to the question and the synthesis-analysis processes should go through the data so that the research questions could be answered. The research questions should be meaningful to both practitioners as well as researchers (e.g. providing theoretical information on the usefulness of a methodology as well as giving guidelines for employing this methodology). Additionally, the research questions should have an effect on the current practices and research, either by altering or by complementing them.

After defining the research questions, a reviewing protocol should be generated and evaluated. The reviewing protocol can be compared to a project plan. It defined the background and the research questions of the study and all the methods that shall be employed in the study. This is done to avoid bias when selecting primary studies.

This protocol should be reviewed - if resources allow it, a group of independent experts could be hired to conduct the evaluation of the reviewing protocol. In the case of students, the protocol should be reviewed by their supervisors.

Evaluating the reviewing protocol concludes the pre-emptive planning phase of the review, after which searching for the primary studies begins. The aim of searching for studies is to gather a wide range of different publications. This is the one of the main distinguishable characteristics of a systematic literature review.

The initial step in searching for primary studies is to define a search strategy. This strategy should be iterative and repeated during the whole process, with corrections made where necessary. Initially, the research question should be broken down into different facets. Each facet should be analysed for possible synonyms, abbreviations and alternative spellings, after which complex search strings can be generated using OR, AND operators, such as in a mapping study.

Searching for studies can initially only be conducted in digital libraries, but for a systematic review to be thorough and broad, other sources must also be included in the search for literature, such as journals and research registers.

As stated by Kitchenham (2007), the amount of literature on a certain topic may be small in the field of software engineering, hence it might be of use to search for literature in connected fields. The entire search process should be documented so that it can be improved, re-evaluated and repeated. Brereton et. al. (2007) define a total of three main issues that must be tackled by researchers when conducting searches for primary studies:

- Search strategies must be alternated and as broad as possible with each restriction having to be justified (such as restricting the search to only specific journals and proceedings);
- Different sources need to be used;
- Since most software engineering search engines are not designed to support systematic reviews, researchers working in software engineering fields must conduct resource-dependent searches by altering their search strategies to suit the search engine and it's capabilities.

### 2.1.2 Appraisal

After gathering the initial list of primary studies, these studies must be evaluated and assessed. To do this, study inclusion criteria must be created. In order to avoid research bias, these criteria should already be initially defined in the review protocol. As with mapping and scoping studies, the initial criteria should be applied based on the abstract and the title, only browsing the full paper when needed.

The appraisal phase is iterative with alterations made in the appraisal process after each iteration. In some cases, it is suggested to create a list of excluded literature, providing a reason of exclusion for each paper. Kitchenham and Charters (2007) specify that this should only be done after the

second or third iteration, since in the initial stage the amount of completely irrelevant papers may be too vast.

In addition to applying the general exclusion and inclusion criteria, one must assess the quality of the primary studies. This can help to assess and evaluate the inclusion and exclusion criteria, guide the interpretation of findings and provide recommendations for further research. Three aspects should be reviewed: systematic error (are the publications unbiased), internal validity (how the design of the study is likely to prevent systematic error), applicability (how the effects observed in the study are applicable outside of the study).

### 2.1.3 Synthesis

Synthesising the primary studies included in the study is initialised with the data extraction phase. This stage aims to design forms to extract data from the primary studies so that information vital to the research questions could be obtained. The data extraction forms should be defined along with the study protocol in order for the study to be unbiased. The form should include data about the researcher, the date of the extraction, general information about the study and all information related to answering the focus questions. To reduce the possibility of the research becoming biased, the form should be defined in the reviewing protocol.

Extracting data from publications should be done independently by two or more researchers with their data being compared and verified by everyone partaking in the research. Marking errors and disagreements requires the usage of a separate form. Peer reviewing these results can also be done by having an independent researcher analyse a random sample of primary studies and comparing the results with the research conducted by the research team.

The results of the data synthesis section should be collated and summarised in a qualitative manner. If found suitable, this data can be complemented with quantitative data, which would require the usage of meta-analysis techniques. Data that has been extracted from the papers should be presented in tabulated form, illustrating the differences and similarities between studies and their outcomes.

### 2.1.4 Analysis

The final phase of a systematic review includes writing down the results of the review and disseminating the results amongst interested parties. The results of a systematic review should be

communicated in an effective manner. Systematic reviews are usually reported in at least two formats, including a technical report and a conference paper. These reports should be peer reviewed as part of the examination process.

### 2.1.5 Requirements

Conducting a full systematic literature review is a rigorous process, due to which it has many requirements that need to be fulfilled. Most of the documentation is done in simple text-documents, which means that text-editing software must be used. Since systematic reviews are often conducted by multiple researchers in parallel, an online shared document editor should be preferred to a standard desktop version. This software should also provide the possibility for adding comments, so that contributors can comment on each other's work. Many tasks require evaluating either the research protocol or the primary studies, which may lead to the need to use an interactive checklist. Since parts of the initial research proposal shall be re-evaluated and modified during the review, version management should be employed to keep track of the changes made. As the initial search queries can result in a copious amount of literature, a tool should be use to manage the bibliography.

Extracting data from primary studies results in a spreadsheet with relevant materials. However, instead of manually filling the spreadsheet one could use a form management tool, entering data from each study into the form and having it automatically generate a spreadsheet. As with most other stages in a systematic review, this phase is often conducted by multiple researchers, hence a task management tool should be employed.

## 2.2 Alternatives to systematic reviews

Rapid reviewing is a literature reviewing methodology that aims to assess what is known about a certain field in a rapid manner by using systematic reviewing methods to search and critically appraise existing research (Giustini, 2016). While they share many similarities with systematic reviews, rapid reviews can be conducted faster and without consuming as much resources (Harker & Kleijnen, 2012).

Rapid reviewing can be seen as a simplified version of a full systematic review - while the latter is undertaken rigorously and often by two separate researchers in parallel, rapid reviews often borrow their methods from systematic reviews by simplifying them or omitting some steps to produce information in a timely manner (CADTH, 2015).

A systematised review is defined as a review that includes one or more elements from the systematic reviewing procedure, yet falling short of claiming that the resulting output is a systematic review (Grant & Booth, 2009). These reviews are usually conducted by postgraduate students as assignments, as they may not be able to draw upon the resources that are required for a full systematic review.

## 2.3 Mapping study

Also defined by Grant et al. (2009) as a systematic map, Petersen et al. (2008) define this methodology as a means of creating a classification scheme and structuring an area of interest, that has so far been widely used in medical studies, but neglected in the field of software engineering. A mapping study provides a structure of the type of research reports and results that have so far been published by categorising them and presenting them in a visual summary (see Figure 2). It requires less effort in terms of analysing the source materials, hence it has so far been widely recommended for areas of research where there is a lack of relevant high quality primary studies. Due to their superficiality, mapping studies cannot be used to identify best practices based on empirical evidence. According to Grant et. al. (2009), a mapping study is best used to specify gaps in existing literature by providing a basis for an informed decision about whether an in-depth review should be undertaken. This can also be seen as the primary weakness of the studies - they lack the synthesis and analysis of their more constrained counterparts. Thus, mapping study results may oversimplify the results or mask heterogeneity between the studies and their findings.

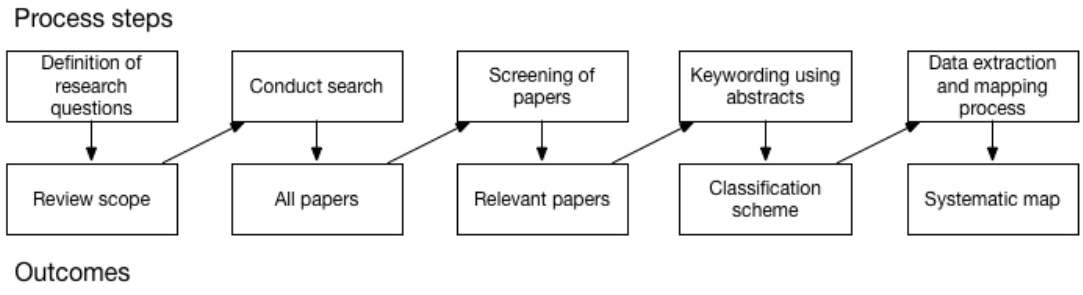


*Figure 2: The systematic mapping process* (Petersen et al., 2008)

### 2.3.1 Search

The initial phase of a mapping study is defining the research question. This is done to assess the scope of the planned study. Mapping studies primarily provide overviews of a certain research area - this should be kept in mind when defining the research questions. The research questions must be broad enough for the subtle work methods of mapping studies to be able to provide answers to them. As stated by Petersen et. al. (2008), a secondary goal of a mapping study may be to identify the databases where most of the research of the area at hand has been conducted.

Primary studies are identified either by using different search strings on different databases or by manually browsing through the proceedings of a preselected conference or the publications of a preselected journal. The search string should be complex in terms of containing multiple string combinations. As a mapping study aims to be as broad as possible, the search string should include many variations of search strings in order to gather a wide amount of different publications. For example, if the study would be about the implementation of agile methodologies in software development processes, the following string could be used: *("agile" OR "rapid") AND ("methodologies" OR "methods" OR "practices") AND ("software development" OR "development" OR "programming").*

Although there are no formal guidelines for the selection of a database, one must also keep in mind the expected breadth of the research.

### 2.3.2 Appraisal

Sorting the papers of the primary study is done by defining specific inclusion and exclusion criteria and pairing them with the publications that have been selected. The inclusion and exclusion criteria should be directly derived from the research question so that the publications that are not relevant to the research question are excluded from the study. Building on the previously mentioned exemplary topic of researching agile methodologies in software development processes, the criteria could be:

- Inclusion: Books, papers and reports that explicitly describe the implementation of agile development methodologies in software development projects and processes. Should several studies be published under the same subject, only the most recent study shall be included in the study.

- Exclusion: The publication only touches upon the topic of software engineering OR agile development methodologies without discussing the relationship between them. The search terms are only mentioned in the abstract. The full publication is not available.

### 2.3.3 Synthesis

Synthesising the papers selected from the primary study is done by systematic coding. The aim of this process is to generate the classification scheme and to organise the selected publications according to their content.

Coding is a two-step process. Initially, abstracts are browsed for keywords and concepts that reflect the contribution of the paper. This also helps researchers identify the context of the research. After this is done, the keywords from different papers are combined so that an understanding about the nature and contribution of the research is gained. Through this a set of categories can be created. Should an abstract be too subtle to draw conclusions or keywords from it, the introduction and/or conclusion of the paper can additionally be analysed. After choosing all the keywords, a category map can be created. This should be done without evaluating each paper in detail, but rather by focusing on the abstract and - if need be - the introduction and conclusion.

Defining the categories of the publications should be done so that the categories are easy to interpret and to pinpoint. Categories should in turn be sorted into different facets, reflecting the research approach and topic area.

### 2.3.4 Analysis

After defining the categories of the papers, each paper should be grouped to one of the categories. A short rationale on why the paper at hand should belong to the category should also be written. The frequencies of publications appearing in certain categories can then be calculated.

The analysis part is focused on presenting these frequencies. By visualising the frequencies, conclusions can be drawn on which categories have previously been emphasised and where the gaps in current research may be. Petersen et al. (2008) propose using a bubble plot to report the frequencies. This is done by creating two x-y scatter plots and adding the categories in the intersections. The size of the bubble represents the number of articles that are in the pair of categories corresponding to the bubble coordinates. The x and y coordinates represent the facets

of the research. If there are more than three facets, additional bubble diagrams can be created. This method allows researchers to give a quick and visual overview of a field.

### 2.3.5 Requirements

The search and appraisal phases of a mapping study do not contain requirements that stand out from other methodologies. The sole exception may be the need for visually dragging and dropping elements of a string. As stated by Petersen et al. (2008), many keyword variations should be explored when defining search queries. Having a visual overview of these search queries and being able to drag and drop different elements in the query can enhance and simplify the procedure for the researcher.

The appraisal phase is most comfortably carried out by using an interactive checklist to compare each paper with pre-set inclusion-exclusion criteria. To point out the rationale and reasoning behind each inclusion or exclusion, a bibliography management software with text highlighting possibilities should be used.

Synthesising data in a mapping study requires more specific tools. Synthesising the filtered primary studies requires researchers to browse the publications for keywords, hence creating keyword clouds would make the process more feasible. This would hasten the process, allowing researchers to skip browsing through entire publications Due to the fact that mapping studies present results via a bubble plot populated graph, a tool should be used that allows to create both regular graphs as well as to visualise data on them. As with the appraisal phase, a bibliography management tool would be useful, to easily look up the rationale behind each keyword or concept extracted into the map.

## 2.4 Scoping study

A scoping study is similar to a mapping study in its end-goals. It aims to rapidly map the key concepts that underpin a research area and the main sources and types of evidence available (Fulop, Allen, Clarke, & Black, 2001). It is usually carried out as a standalone project, especially when the area being researched is complex or has not been reviewed comprehensively before. The breadth and depth of a scoping study depends on what the purpose of the review is. According to Arksey (2005), there are four different reasons a scoping study could be carried out:

- To examine the extent, range and nature of research activity;
- To evaluate the need for a full systematic review;

- To summarise and disseminate research findings;
- To identify gaps in current literature.

Based on these four reasons for conducting a scoping study, the studies can be viewed from two different perspectives. In the first two, a scoping study can be seen as a method or a part of an ongoing process, with the aim of ultimately undertaking a full-scale systematic literature review. The final two approaches see scoping studies as a methodology in its own right.

### 2.4.1 Search

Similarly to mapping studies, a scoping study is initialised by defining a research question. Although scoping studies are not guided by a highly focused research question, they may guide the way search strategies are built.

When defining a research question, it is important to oversee all aspects of the question. For example, if one were to study how widely distributed user interface patterns are used, then it must also be defined, which patterns should be included as DUI patterns. Maintaining a wide approach is vital, since narrowing the different facets of the research question down may reduce the likelihood of finding relevant publications. However, this must be done carefully, since the opposite scenario may generate an unmanageably large amount of publications.

After defining the research question, relevant publications must be sought. One of the main characteristics of a scoping study is its breadth - identifying primary studies is done in a comprehensive manner with all publications selected that may contribute to the central research question. To achieve this, the researcher should search for relevant publications in electronic databases, reference lists, key journals as well as relevant organisations and conferences.

Each of these sources has guidelines for conducting the search process. Electronic databases should be searched by using complex keyword combinations. Should these search strings provide too much results, the search strategy can be revised and implemented again.

Reference lists of the papers selected in the previous search should also be checked. This should be done by especially focusing on previously conducted literature reviews, so that eventually a saturation point would be reached, where the publications extracted from the first primary study papers would start to repeat themselves.

Various key journals should also be manually searched to cover publications that might have gone missing in the previous searches, due to the incompleteness of electronic databases. All titles that seem relevant to the research question should be covered.
One of the most salient methods proposed by Arksey et. al. (2005) to search for primary studies is to contact different organisations related to the research field. This may lead to discovering studies that may have gone missed in the previous searches.

### 2.4.2 Appraisal

Gathering a broad selection of different primary studies will likely lead to a surplus of irrelevant publications. Similar to systematic reviews and mapping studies, the appraisal phase of a scoping study works with inclusion and exclusion criteria. Criteria can also be developed post-hoc and re-evaluated as literature is being analysed due to increasing familiarity with the subject. This should be done based on the abstract alone - should the abstract leave it unclear whether the paper should be included or excluded, the full paper can also be analysed. Based on the abstracts, only papers that firmly exclude the study should be excluded. After the first studies are excluded, the full papers should also be analysed, since the abstract alone may not represent the content of the whole study (Badger, 2000).

### 2.4.3 Synthesis

Analysing the studies that were included in the appraisal phase is done similarly to a systematic review or a meta-analysis. The specific technique Arksey and O'Malley (2005) propose is called "charting", a data extraction method that includes analysing the studies by charting and sorting different key issues and themes (Ritchie & Spencer, 2002).
Charted data should include both general information about the study (e.g. the authors and the year of the publication) as well as more specific information about the context of the study (e.g. the methodology employed).

### 2.4.4 Analysis

Literature review methodologies such as the systematic review only give an overview of literature deemed relevant to the study in their final reports (Kitchenham & Charters, 2007). Arksey and O'Malley (2005) argue about the effectiveness of this, stating that studies not included in the final

review may then be hidden from publication. Hence, the final report of a scoping review aims to give an overview of all the literature reviewed.

After charting information from the studies, a narrative account of the findings should be presented. This will serve as the identifier of gaps in current research.

### 2.4.5 Requirements

As a scoping study is similar to a mapping study in its goals, it shares many of its requirements. The search phase could be complemented with a visual tool to aid generating complex search queries and have an overview of all the different facets of the research questions. Since searching for primary studies is done in multiple phases, a revision history tool could be used to keep track of changes made to the queries and overall search strategy. As with a mapping study, a checklist can be used to include or exclude primary studies from the research. Additionally, software that is able to extract abstracts from papers can be useful, since most of the appraisal should be done by only browsing the abstract. Charting data extracted from a study should be done using a spreadsheet, the final report can be done in a text editor of choice, both of which can be found in most document editing software suites.

## 2.5 Umbrella review

The umbrella review is a type of an overarching literature review that was created by the Cochrane Collaboration after the emergence of systematic reviews in many fields of knowledge (Mccutcheon, Lohan, Traynor, & Martin, 2015). As systematic reviewing became more common, there rose a need for a methodology to review existing reviews (Hartling, Chisholm, Thomson, & Dryden, 2012). Conducting an umbrella review allows researchers to address a broad scope of issues related to a particular research topic (Mccutcheon et al., 2015). Umbrella reviews are principally undertaken to summarise evidence from more than one synthesis of existing research evidence at a variety of different levels.

### 2.5.1 Search

Aromataris et. al. (2014) state that planning an umbrella review should be initialised by generating the title of the review, specifying that the title should be informative and give a clear indication of the topic of the review. Additionally, the topic should include the phrase “An Umbrella Review”,

so that the type of document is easier to represent. This guideline should be followed in all literature reviews.

The research question of an umbrella review should ideally be defined in accordance to the PICO mnemonic (Richardson, 2013). The question should thus attempt to define four components:

- Population
- Intervention
- Comparison
- Outcome

When defining the reviewing activities, researchers must also cover all the main background elements of the topic under review. The background description should be a 1000-word document that defines what the review attempts to find out and who the target audience is. If an umbrella review on a similar or identical topic already exists, justifications should be provided on how the proposed review is expected to differ from it or contribute to it. The questions proposed in the background description are to be used as a basis when searching for relevant studies. As umbrella reviews are used to analyse the findings of previously conducted reviews, studies are seen as syntheses of research evidence including systematic reviews and meta-analyses.

The exact strategy for locating research syntheses should be defined in the research protocol, including the key terms to be used and the resources to be searched. Using predefined search filters that exist in various databases can aid in this phase. Using the keywords “systematic” or “meta-analysis” may prove valuable when filtering out literature reviews from other studies. The search terms used should be broad enough to capture all relevant reviews - if the publication turns out to be irrelevant, it shall be excluded in the appraisal phase.

Aromataris et al. (2014) have suggested using a three stage process when searching for primary reviews:

- Identifying keywords, analysing the title, abstract and index terms to describe relevant reviews;
- Constructing database-specific search filters;
- Searching the reference lists of all included reviews.

### 2.5.2 Appraisal

To determine which studies should be included in the review, inclusion criteria should be clearly defined. This should be done multi-dimensionally:

- The phenomena of interest should be clearly defined and should be congruent with the review objective;
- The outcomes of the study should be relevant to the research question;
- The type of study has to be a type of research synthesis;
- In some fields of research, other factors may be included to the criteria (such as the population as well as the context of the study).

All studies that are included in the review should be assessed for methodological quality. This should be done using a criteria-based checklist, that can be scored for each criteria that is either met, not met, unclear or not applicable. Each criteria can have a different weight. The final decision as to whether the study should be included or excluded is decided by the researchers in accordance to the criteria checklist - the threshold of acceptance should be defined earlier in the research protocol.

### 2.5.3 Synthesis

Once all the primary studies have been filtered, they can be analysed to collect relevant details and data to include in the review. The methods with which to extract data from the studies should be defined in the research project, to maximise consistency.

Joanna Briggs' Institute has developed a data extraction tool that can be used to extract data from systematic reviews and research synthesis to conduct umbrella reviews. This form allows researchers to fill out different pre-set fields, mapping different data about the publication, such, as the type of review, conclusions and comments. Although this form is mainly designed for medical studies, it can be adapted to other fields as well.

Although the exact method by which the final data shall be presented, should be defined by the researcher in the initial research protocol, a tabular presentation of findings is recommended where overall effect estimates from the systematic reviews are presented. In the cases of presenting quantitative data, the number of studies that support the outcome and the heterogeneity of the results should be reported upon.

### 2.5.4 Analysis

The final document of the umbrella review should include all data about the conclusions of the review, as well as information about the researchers, the abstract etc.
The body part of the document should begin with a background definition, covering all the main elements of the topic under review. This section should conclude with a statement that a preliminary search for previous umbrella reviews on the topic was conducted. The objectives of the review should also be clearly stated.

### 2.5.5 Requirements

Umbrella reviewing emphasises the importance of documenting many phases of the research (such as writing a background description), hence text editing capabilities are important. When analysing primary studies, keywords should be derived from the paper, hence creating word clouds can be productive. Additionally, bibliography management software that allows researchers to automatically extract keywords and abstracts should also be employed. An interactive check list can hasten the appraisal phase; the relevance threshold ratings should be stored in a data table. As stated in the synthesis section, a pre-made form can be used to collect data from the publications - this form should be generated virtually and interactively. This data should also be presented in a tabular manner.

## 2.6 Meta-analysis

Meta-analysis involves the use of statistical procedures to evaluate and analyse research findings across different studies (Hwang, 1996). It is essentially used to combine findings from previously conducted independent studies and is often conducted to analyse a set of systematic literature reviews on a topic (Crombie, 2013). As a meta-analysis is used to combine data from different quantitative studies, it can be used as part of a systematic review that aims to analyse different quantitative studies. Hence, most meta-analysis guidelines focus on the analysis and synthesis aspects.

### 2.6.1 Search

As stated by Crombie (2013), a thorough systematic review lies at the heart of a meta-analysis. This principle is reflected in what Crombie (2013) names the main requirement for a worthwhile

meta-analysis – to find qualitative source studies. However competent the meta-analysis, if the studies it is based upon are flawed, partial or otherwise unsystematic, then the meta-analysis may provide inaccurate conclusions.

A meta-analysis requires a comprehensive search strategy that encompasses several electronic databases. The strategy must be written as a sequence of requirements – include papers that contain specified terms, exclude papers that do not meet a specified inclusion criteria or include studies that follow certain research designs.

### 2.6.2 Appraisal

The appraisal phase is defined by Crombie (2013) as the quality assessment, during which all relevant studies must be analysed to determine which are sufficiently well conducted to be worth including in the analysis. To exclude any bias, explicit and objective criteria for exclusion and inclusion must be used. When using criteria, quality scores can be derived from comparing each paper to the criteria. The papers with lower ratings may be excluded while those with higher ratings should be included in the meta-analysis.

### 2.6.3 Synthesis

When synthesising the primary studies, a coding sheet must be derived. This sheet should list the fields (variables) that should be extracted from each study and how each should be coded (Lipsey & Wilson, 2001). When synthesising the studies, effect sizes must be taken into account, as they provide a way to standardise effects across studies using different methods. Data must be entered to a coding sheet one row at a time, including data about the publication as well as the outcome that was measured. The findings from the selected studies should be combined using appropriate statistical methods.

### 2.6.4 Analysis

Although a written summary of the findings is presented when summarising the findings of a meta-analysis, due to the quantitative nature of the review, different graphs should be employed to present the findings (Tanner-smith, 2013). These graphs have to be conducted in a studious manner, since if they are poorly constructed, they can be misleading and harm the overall quality of the review. Finding the balance between accuracy, simplicity and clarity is essential. The most

widely used graph type in meta-analysis studies is a forest plot, which visualises effect size estimates and confidence intervals for each study included. Funnel plots, bubble plots and other similar plots should also be used when appropriate and necessary.

### 2.6.5 Requirements

Since most meta-analysis guidelines focus on analysing and synthesising data, specific requirements inherent to meta-analysis studies can be derived from those phases. Meta-analysis studies deal with quantitative studies, hence software that can analyse quantitative data may be useful for meta-analysis studies. These applications should also be able to build graphs based on the data included in the review.

## 2.7 Critical review

A critical review – also referred to as a critique – is a detailed commentary and analysis of literature (ELS Queen Margaret University, 2011). Critical reviews can be conducted as stand-alone research projects or as preparations for a systematic literature review. Although there are guidelines to conducting literature reviews, it lacks the formal requirements and structured approach of reviewing publications. More emphasis is set on the conceptual contribution of each item of included literature (Grant & Booth, 2009). Thus critical reviews are more often used as starting points in larger research projects.

### 2.7.1 Search

Due to the lack of thorough formal guidelines, there are no methods specified in terms of how to find relevant literature. Building upon other methodologies, it may be speculated that the general approach remains the same – beginning the searching phase requires defining a research question and an objective of the research, after which a thorough search of different relevant databases should be carried out. The initial phase of the review should also define the aim of the research and the rationale behind it.

### 2.7.2 Appraisal

As there is no formal specification on how relevant literature should be searched, there is likewise no formal quality assessment specified. Most primary studies are analysed to evaluate their contribution.

### 2.7.3 Synthesis

The results and findings of a each reviewed publication should be presented in a clear and consistent manner, in line with the previously defined aim of the research. The results should be presented with visual methods if appropriate, such as graphs or tables. There should be no gaps in the final results – if there is an absence of relevant data, the gap should be explained thoroughly.
In contrast with many other methodologies, a critical review requires the researcher to read through all primary studies entirely. This allows researchers to get a general idea of the publication and find answers to questions such as:

- Is the study clearly laid out?
- Are the results clearly presented?
- What are the main findings?
- What methodology has been used?

### 2.7.4 Analysis

In the final report a discussion should be provided interpreting the findings of the overall review. This part should include the evaluation of strengths and weaknesses of the findings as well as speculate on their significance in further research in the field. The final report should also be concluded with a summarising paragraph, defining both the findings of the research as well as it's gaps and weaknesses.

### 2.7.5 Requirements

The requirements for a critical review are harder to define due to the lack of formal guidelines for the methodology. As with literature reviews generally, this methodology requires the possibility of managing literature, text editing and storing data.

## 2.8 Alternatives to critical reviews

An overview is a generic term used to describe any summary of literature that attempts to survey some literary publications and describe their characteristics (Grant & Booth, 2009). Although they can provide a broad and comprehensive perspective of a topic area, due to the broadness of the term, they can be used with varying methods and differing degrees of systematisation (Oxman, Cook, & Guyatt, 1994). An overview can be seen as an alteration of a critical review due to its similar end goals and freedom of choice when selecting the methods for conducting the review.

A systematic search and review is defined by Grant & Booth as a reviewing methodology that combines the strengths of a critical review with a more thorough search process. It often addresses broad questions and incorporates multiple study types rather than focusing on a certain study design.

## 2.9 Other reviewing methodologies

In addition to the methodologies defined in the previous paragraphs, Grant & Booth (2009) have catalogued other literature reviewing methodologies. These methodologies lack a set of formal guidelines due to them only being used in certain fields of science or due to the infancy of the methodology.

### 2.9.1 Qualitative evidence synthesis

A qualitative evidence synthesis is defined by Grant & Booth (2009) as a method for integrating findings from various qualitative studies. A qualitative evidence synthesis can be distinguished by its end-results. While other reviews may aim to aggregate different studies together, the methodology at hand aims to create an interpretative and broadening understanding of a particular field of interest. Methods for this approach are still being developed and there is considerable debate on which methods are most suitable to use with a qualitative evidence synthesis.

### 2.9.2 State of the art review

State of the art reviews aim to address more current matters in contrast to the retrospective approaches of other traditional literature review methodologies. These reviews may offer new insight or perspectives and find new possible areas of research and they are typically carried out to address more current matters (Grant & Booth, 2009). These review types may be suitable for

researchers new to certain fields, while it allows them to derive the main characteristics of a research area without requiring them to work through an excessive amount of literature.

### 2.9.3 Mixed methods

A mixed methods review can refer to any combination of different methods where at least one of the components is a literature review, usually systematic (Grant & Booth, 2009). This term is often used to describe qualitative studies that employ different methods to analyse and synthesise quantitative data.

### 2.9.4 Analysing qualitative content

Although most literature reviewing methodologies describe different approaches for analysing and synthesising research findings, they do so on a perfunctory level, without describing the work methods required in detail. This leads to the need to describe approaches that can be employed to analyse qualitative content.

Shannon & Hsieh (2005) propose three different approaches to analysing qualitative content – conventional, directed and summative (see Table 1). All three approaches aim to interpret qualitative data, but vary in the contexts they are suitable in and the exact methods they employ.

Conventional content analysis is generally used when existing theory or research literature on a phenomenon is not thorough. Data is analysed and read wholly and iteratively to achieve a sense of the whole, after which codes are derived. A coding scheme is then developed, highlighting the relationships between different codes and definitions are provided for each code. The primary strength of a conventional content analysis lies in its lack of preconceived categories, allowing more diverse to be generated. However, conventional content analysis may fail to develop a complete understanding of the field of study. This can be avoided by peer activities, negative case analysis and other methods.

Directed content analysis employs a more directed approach than a conventional content analysis. Key concepts are initially identified as coding categories, after which definitions are proposed for them. Coding can be done either by browsing through the data and deriving initial coding categories or coding categories may be defined before analysing the data. Directed content analysis can help strengthen existing research, yet it poses many risks including the possibility of being

biased – researchers may be more likely to find supportive evidence to preconceived codes than non-supportive.

Summative content analysis starts with identifying certain words in text with the goal of understanding their contextual use. Data analysis starts with searching for occurrences of the words that have been identified, after which word frequency counts are calculated. A summative approach to content analysis is an unobtrusive way to study a field of interest, allowing researchers to analyse how terms and words are used in context (Babbie, 2010).

All three approaches may be used in various literature reviewing methodologies, the final choice is determined by matching the research purpose and the state of the field of interest with the corresponding analysis technique.

*Table 1: Comparison of different content analysis approaches* (Hsieh & Shannon, 2005)

| **Type of content analysis** | **Study starts with** | **Timing of defining codes** | **Source of codes** |
|---|---|---|---|
| Conventional content analysis | Observation | Codes are defined during data analysis | Codes are derived from data |
| Directed content analysis | Theory | Codes are defined before and during data analysis | Codes are derived from theory or relevant research findings |
| Summative content analysis | Keywords | Keywords are identified before and during data analysis | Keywords are derived from interest of researchers or review of literature |

# 3 Literature reviewing software

As described in the previous sections, each literature methodology is built upon different procedures for accomplishing their goals in a systematic manner. Implementing each procedure poses different requirements for the person conducting the review. These requirements may vary but they may also overlap for different methodologies.

Although most formal guidelines offer insight on how the search, appraisal, analysis and synthesis phases of different methodologies should be carried out, they rarely offer insight into the existence of different tools that could help address the requirements these methods pose.

Using interactive tools when conducting literature reviews can hasten the entire process of carrying out the review. As it also improves the transparency of the research, it may also improve the quality of the final result of the research.

The overlapping of requirements that different methodologies set makes it possible to propose software that is unanimously best suitable for most review types. In general, a researcher would need to have access to two different software solutions to conduct the research: bibliography and reference management software and software to analyse quantitative and qualitative data extracted from the publications. Additional requirements may be addressed by specific software (e.g. generating graphs).

The following list aims to propose suitable tools for each requirement that different methodologies propose. Since requirements may overlap between methodologies, the list is divided by requirements instead of methodologies.

## 3.1 Bibliography and reference management

Most literature reviewing methodologies revolve around finding and gathering all publications relevant to the proposed research question. This places storing and managing publications in a central role amongst reviewing requirements.

Researchers must be able to store the primary studies they have found, possibly by cataloguing them in custom groups. Using respective applications would give the researcher a better overview of the publications gathered, but it can also allow the researcher to analyse the publications, derive data from them and go through other processes that may be vital to other reviewing requirements. A good literature management tool should allow the user to store publications, but it should also excel in what it allows the user to do with them.

Since forward and backward searching references found in primary studies may lead to further relevant publications, these tools should allow users to easily store and look up references. Other functionality concerning the contents of the publication should also be supported by the same software. That functionality would more likely serve the researcher when dealing with the requirements of the appraisal phase.

Once the researcher has conducted the search on the databases that had been previously selected, the primary studies selected in the search phase must be thoroughly analysed to determine whether they should be included or excluded from the review.

Different methodologies propose different specific requirements in terms of analysing the primary studies. While some methodologies suggest a subtle approach by having the researcher only browse keywords and the abstract sections of the studies selected, other methodologies may employ a more systematic approach, requiring researchers to thoroughly analyse each publication to determine whether it should be included or excluded from the review. The tools proposed should be able to extract relevant meta-data from the publications for quick reviewing as well as provide researchers with tools to analyse publications in depth.

Most literature reviewing methodologies foresee researchers comparing primary studies to a pre-defined list of inclusion and exclusion criteria. In many cases, this requires the reviewers to provide a clear rationale for the reasoning behind the exclusion or inclusion of a specific publication. This can be done by creating a fillable form or a checklist based on the exclusion and inclusion criteria. This form can be filled for each primary study. Clear rationale for including or excluding a publication should be provided, hence referencing relevant sections of the studies is necessary, either by citing them in the form or highlighting them in a bibliography management tool.

The following list summarises the most popular bibliography management applications currently used, their main features and drawbacks and why should one be considered over the other.

According to the University of California (2015), the six most popular reference managers are Zotero, Mendeley, Endnote, Refworks, Papers and Readcube.

### 3.1.1 Zotero

Zotero was initially launched as a Firefox add-on – although they have since then released a desktop application that can be used with other web browsers, the Firefox add-on remains the core product. The main benefit of Zotero is its ability to detect papers and publications in the browser.

Users are able to save the paper being viewed to Zotero, which automatically analyses it for data such as keywords, abstracts, authors. Zotero also hosts multiple additional applications for more popular text editing applications such as Microsoft Word, LibreOffice and Google Docs, allowing researchers to automatically generate references from their Zotero database.

Zotero falls short in file management, as most studies are simply stored as references and browsing the file has to be done via a stand-alone PDF reader. This may prove to be uncomfortable for the researcher carrying out a literature review, which requires analysing different publications. Additionally, Zotero lacks the functionality to store data about the papers or modify them in any way, for example through highlighting and commenting.

### 3.1.2 Mendeley

As with Zotero, Mendeley is capable of managing publications both as a browser add-on as well as through a desktop application. In terms of reference management, Mendeley is capable of generating references from publications that have been stored in it. However, a plugin to generate references is only available for LibreOffice and Microsoft Word.

Mendeley enables researchers to directly view publications, additionally it allows researchers to interact with them. Text can be highlighted; revisions can be made in the form of comments. However, all these functions are done internally in the application, cross-application compatibility is not supported, which forces all researchers working on a single project to use the same software in order to share notes.

### 3.1.3 ReadCube

ReadCube was launched in 2011 as a desktop application, providing users with access to different materials through partnerships with several publishing companies. This is one of the core advantages of ReadCube, since references of articles can often be found simply by clicking on them. ReadCube allows researchers to apply their institutional proxy data, enabling them to view publications that may be behind a paywall.

ReadCube is also characterised by its recommender system, which generates potentially interesting publication suggestions daily, based on your reading history. This can lead researchers to additional relevant papers and the insight gained may prove to be valuable from the perspective of writing a literature review.

ReadCube lacks sharing capabilities and and is more restricted to its desktop application, hence although it offers more functionality, it can be more tedious to use.

### 3.1.4 Endnote

Endnote is a commercial tool that was developed to manage bibliographies and references while writing essays and articles (Thomson Reuters, 2016). Endnote offers two desktop solutions (basic and advanced) as well as an iPad application, which can be considered to be an extension of the desktop application.

Endnote allows researchers to conduct database searches directly from within the application. PDF files can directly be accessed and downloaded into the Endnote library.

Endnote is inherently similar to Mendeley in the functionality it provides. In addition to providing researchers with cloud-based storage and an optional web application to remotely access their data, Endnote also features a Microsoft Word plugin that allows researchers to cite publications included in their research.

### 3.1.5 Refworks

Refworks is a web-based reference manager initially released in 2004 (Proquest, 2016). Although being primarily a web application is beneficial in terms of being able to access data anywhere, it's primary shortcoming is its incapability of offering offline functionality.

Refworks stands out by offering multiple complementary plugins:

- Write-n-cite, a Microsoft Word plugin for both Windows and Mac OS X versions of Word;
- RefShare, a tool that enables researchers to make their databases public;
- RefMobile, a mobile phone interface;
- RefGrab-It, a tool to grab bibliographic information from websites.

### 3.1.6 Papers

Papers is a reference management tool initially developed for Mac OS X and later developed for Windows (Labtiva, 2016). In terms of functionality, Papers does not stand out from many of its counterparts, as it also offers cross-device functionality, citation plug-ins for text editors and directly searching databases from inside the application.

Papers features the possibility of minimising the user interface, hence making it easier to focus on the publication. Additionally, publications can be highlighted, underlined, annotated. All data can also be downloaded and used offline.

## 3.2 Analysing qualitative content

Although many bibliography management tools allow researchers to conduct simple procedures on primary studies, they fall short on the level of depth required by most literature reviewing methodologies. For a study to be systematic and transparent, the qualitative content of the primary studies gathered must be analysed thoroughly (Seuring & Gold, 2012). Reference management tools often fall short on categorising, grouping and deriving information from publications.

This places CAQDAS (Computer Assisted Qualitative Data Analysis Software) at a central role in most literature reviewing techniques (Cabraal, 2012a). As such, a tool that allows the researcher to classify and arrange information as well as to examine relationships in the data should be employed. The following list provides brief overviews of different CAQDAS solutions as proposed by the University of Surrey, covering both commercial as well as freeware solutions with the exception of MiMeG, which is no longer in development.

### 3.2.1 NVivo

NVivo is a tool for qualitative data analysis, aimed at researchers working with text-based and/or multimedia information that require analysing (QSR Research, 2015). NVivo enables researchers to analyse qualitative data in the form of studies and publications and to code their research. As it is aimed at more thorough endeavours that deal with large amounts of data, it should be used in reviews that deal with a considerable amount of literature

Using NVivo can help researchers identify different patterns in literature, which can be in turn categorised (Cabraal, 2012). This allows researchers to map different trends occurring in the surveyed literature as well as to pinpoint the publications that cover a specific category. Changing the category structure is possible during the reviewing process.

Additionally, NVivo provides most other functionalities that may be required by different methodologies. Analysing PDF documents, linking specific notes and sections of publications to a defined category and storing the publications are all provided.

The main drawback of the software is the lack of an organic reference manager. However, this can be substituted, since NVivo offers cross-application compatibility with different reference management tools, such as Zotero and Mendeley.

### 3.2.2 Atlas.ti

Atlas.ti is a flexible qualitative data analysis tool, allowing researchers to analyse different phenomena in unstructured data (Lewins & Silver, 2014). Its flexibility has lead it to being used in different fields of science.

Similarly to many of its competitors, Atlas.ti allows researchers to manage PDF documents. Additionally, it allows researchers to display up to four documents at a time, which may be useful when comparing different files (Silver & Lewins, 2014). Coding is also supported, although it lacks a functioning hierarchical structure, which may make systematically coding concepts or categories more difficult. Another characteristic of Atlas.ti is the embedded Google Earth plugin. Although this may not be of use in the concept of a literature review, it enables a new dimension of geo-referencing data.

### 3.2.3 QDA Miner

QDA Miner is a mixed-method qualitative data analysis tool that enables analysing textual and graphical data (Silver & Lewins, 2007). It enables most features expected from a CAQDAS tool, such as coding and connecting publication references to coded concepts. According to Silver & Lewins, QDA Miner excels at simple functions, allowing researchers to colour code concepts and retrieve data in a tabular format. It also allows researchers to analyse their codes, detecting co-occurring and overlapping codes in the data. It also stands out by using a report management tool, which allows researchers to organise results from their research in a convenient manner.

### 3.2.4 Dedoose

Dedoose is a web-based qualitative research application, which means it can be used without the need to install any software (Silver, 2012). Although this allows researchers to access their data regardless of the device they are using, it also allows them to work only while connected to the Internet. Although Dedoose offers a wide range of tools, many of them are specifically designed for mixed methods approaches. The overall process of using Dedoose requires a code based

approach (similarly to most CAQDAS software), yet some functions are more quantitatively oriented than most alternative tools. Dedoose also stands out with it's well developed collaborative work aspects, as it is an online application instead of a desktop application. This makes flexible collaborative working possible, allowing researchers to work concurrently and tracking the actions of different researchers in the process.

### 3.2.5 Digital Replay System

DRS is a freeware research tool that allows researchers to exploit heterogeneous data (Silver & Lewins, 2009). It is similar to other CAQDAS solutions as it allows analysing both textual data as well as multimedia formats, it stands out as it allows multiple multimedia tracks to be synchronised as well as the combination of systems logs with qualitative data records, thus making it more suitable for analysing multimedia file types (University of Nottingham, 2011). DRS does not enable researchers to collaborate individually on a shared project.

### 3.2.6 HyperRESEARCH

HyperRESEARCH is a qualitative content analysis tool first developed in 1990 (Guide & Kinder, 2010). It allows researchers to analyse both textual as well as multimedia data and to create & assign codes. Coding is not hierarchical and all codes are stored alphabetically. HyperRESEARCH stands out due to its hypothesis testing tool that allows users to formalise and save searches, thus helping researchers to determine whether the coding supports any perceived assumptions. It also allows researchers to build code maps, displaying the connections between codes and their associated data.

### 3.2.7 MAXQDA

MAXQDA is a qualitative data analysis tool that enables the analysis of various qualitative data types, ranging from textual data to focus group transcripts and tweets (Silver & Lewins, 2014). MAXQDA stands out in its compact user interface as well as its use of colour schemes. Different colours are used to visually differentiate aspects in research, which can make grasping copious amounts of data easier. Coding can be done both hierarchically and not. Different visual tools can be used to create conceptual maps, code relation illustrations or tag clouds.

### 3.2.8 Quirkos

Quirkos is a CAQDAS tool created in 2013 as a software solution that is accessible to those without extensive research expertise as well as to professional researchers. Emphasis was placed on ease of use – as a result, the user interface is considerably different from other qualitative content analysis tools. Although its simplicity and cross-device capabilities (Quirkos can also be used on responsive devices) give it a good advantage, its simplicity lead to the lacking of some functionality that many of its alternatives provide, such as annotating and linking sections of text.

### 3.2.9 Transana

Transana is open source data analysis software that allows researchers to analyse and transcribe digital video, audio and still image data (A Lewins & Silver, 2006). Although the source code is freely editable, it is originally developed for the analysis of video data, which makes it unsuitable for researchers dealing with textual literature reviews.

## 3.3 Other requirements

### 3.3.1 Constructing complex search queries

Finding primary studies that are essential to answering the proposed research question is a vital step in the process of writing a literature review. Although the act of generating complex search queries is best explained in the context of a mapping study by Petersen, Feldt, Mujtaba et. al. (2008), the method they propose can be applied in most other methodologies likewise.

Search queries should contain different keywords that are relevant to the field being researched – to avoid a surplus of irrelevant literature, combinations of these keywords should be used when searching for publications. These combinations should be used in many different variations by using Boolean statements for each keyword. Depending on the amount of proposed keywords, these statements can contain ten or more variables, which makes keeping track of the variations used difficult.

Applications that can assist generating and modifying these search queries can hasten the searching process for the researcher. Ideally these applications should allow the researcher to clearly divide different parts of the search queries and swap them with one another by drag and dropping variables or by some other simplistic method.

A potential solution to managing search queries consisting of multiple variables is to use software designed to create concept or mind maps. In addition to making it fairly easy to interchange query elements, such tools can be helpful in visualising research findings (see Figure 3).

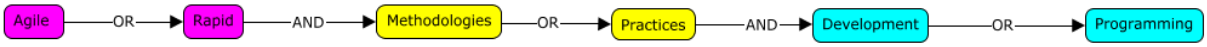


*Figure 3: Example of a complex search query built using cMap Tools*

### 3.3.2 Generating graphs

Most studies and reviews dealing with quantitative data present their findings in the form of graphs. Graphs are used to convey the results of meta-analysis studies (Tanner-smith, 2013), but they can also be used to present quantitative data derived in qualitative studies. From one perspective, graphs can aid in informing the user about the study results, but they can also aid researchers in interpreting the study results.

The amount of statistics the graphs are based upon can vary depending on the type of the study, hence both tools for analysing copious amounts of quantitative data as well as tools for creating subtle graphs with limited data sets shall be proposed.

Studies dealing with smaller amounts of data may rely on the built in chart generating features of most modern text editors, such as the ones built in Google Docs, Microsoft Word and LibreOffice. All of these text editors allow generating different charts with relative ease.

In terms of studies dealing with quantitative data, a statistical analysis tool should be used. A well-known option is SPSS, an advanced software package that allows data management, documentations and analysing data. All functions such as determining the significance levels of variables or the means and their differences are achievable by multiple methods. The built in console returns data in the form of tables and complements it with charts (e.g. a scatter-plot diagram for checking extreme values) if necessary.

### 3.3.3 Editing and sharing collaborative documents

Many literature reviewing methodologies promote collaborative work as well as peer reviewing as a vital component of a literature review. As an example, systematic reviewing should be conducted by multiple researchers. As a result, tools that allow users to directly upload their work to the cloud as well as to track individual changes, can make collaborative working more resourceful.

Of the three bibliography management tools mentioned beforehand, Mendeley is the only one that allows collaborative work between researchers. In addition to sharing publication libraries and folders between team members, Mendeley shares all notes, highlights and other data in between researchers.

# 4 Case study

To evaluate how employing different tools proposed in the previous section may have an effect on the process and the end result of a literature review, an exemplary review was carried out. This literature review aimed to map the state of art of distributed user interfaces in the field of user interface design.

Based on the methodologies described above, a systematised review was chosen as the most suitable option. According to Grant & Booth (2009), a systematised review attempts to include some elements of a full systematic review, while omitting others. As a result, although it shares some common characteristics with a systematic review, a systematised review cannot be classified as a full systematic literature review. As a full systematic review is a time consuming undertaking and requires the participation of multiple researchers, a systematised review consisting of as much systematic review methods as possible, was deemed appropriate for the case study.

## 4.1 Method

The following section provides a summative overview of the research protocol that guided the reviewing process. A systematised reviewing process was chosen as the suitable methodology for the review at hand. As defined by Grant & Booth (2009), a systematised review attempts to include one or more elements of a full systematic review process while stopping short of claiming that the final end-result can be seen as a systematic review. A systematised review is often conducted as under- and postgraduate student assignments, since full systematic reviews are time-consuming and often require the collaboration of multiple researchers (Kitchenham & Charters, 2007). As a result, certain elements were derived from Kitchenham's description of a systematic reviewing process. The reviewing procedure was set in the research protocol as the initial step and was iteratively complemented during the rest of the research.

The literature review was conducted as an expansion of the literature review previously conducted by Shmorgun & Lamas (2015), that aimed to give an overview of the research on the design of distributed user interfaces (DUIs). This work analysed where DUI research is published, how it has developed during the past decades, what are the main reasons DUI research is conducted and what are the primary design approaches and techniques used in a DUI design process. A re-evaluation of the findings of this paper was achieved by employing a systematised reviewing strategy while using different software to support conducting the review.

### 4.1.1 Research questions

The literature review was conducted on the primary studies identified by Shmorgun & Lamas (2015). The review of these studies aimed to answer three research questions:

- What design motivations does DUI research serve?
- What are the approaches and techniques used for the design of DUIs?
- What aspects do teams focus on when designing DUIs?

As their chosen research questions directly influenced their search for literature, no major changes were made in defining the primary research question of the literature review at hand. The secondary research question was defined during the data analysis procedure. Hence, the research questions this review aimed to answer were:

- RQ1: Why is DUI research carried out?
- RQ2: What are the main outcomes of DUI research?

### 4.1.2 Sources

This literature review built upon the publications identified by Shmorgun & Lamas (2015), which were found by conducting searches in different digital libraries, such as the ACM Digital Library, IEEE Xplore, ScienceDirect, Springer Link, Taylor and Francis Online. Additional relevant publications were identified by conducting forward and backward searches from the initial set of publications.

### 4.1.3 Quality assessment

As determined by Kitchenham & Charters (2007), a quality assessment of the studies included in the review must be carried out to guide the interpretation of findings, determine the strength of inferences and to guide recommendations for further research. To assess the quality of the studies included in the review, a set of assessment criteria was composed, loosely based on the approach described by Dybå & Dingsøyr (2008). Certain criteria was excluded due to its irrelevance in the current context and some criteria was added. Dybå & Dingsøyr (2008) describe their proposed quality assessment approach as a means to identify the rigorousness, credibility and relevance of the papers provided. Out of these three metrics, rigorousness and relevance were focused upon in the context of this literature review, since the criteria associated with defining the credibility of the

publications mostly required the publication to focus on a user study (e.g. the presence of a control group or a set of participants). The criteria that was used to assess the quality of the publications is as follows:

1. Is the study based on empirical evidence?
    a. If the study is based on empirical evidence, does it provide information on the design process?
2. Are the aims of the study clearly reported?
3. Does the study provide clearly stated findings with justified conclusions?
4. Did the study provide clear value for research or practice?
5. Was the study published after 2005?

The fifth criterion was added after primary analysis of the studies included in the review. As many publications were published in the in the early nineties, publications that were less than ten years old were deemed of better quality than their counterparts. This was apparent in publications such as the study describing DistEdit, where the whole design process was affected by the technological constraints posed by the technology available at the time (Knister & Prakash, 1990). Ten years was deemed to be a suitable limit, as publications written after 2005 consisted of little to none technological constraints that have been solved nowadays. A sub-criterion was also iteratively added, after witnessing the overall lack of describing the design process of DUIs. Each criterion was graded on a scale of 0 to 1 with positive answers being graded with 1 and negative answers with 0 (e.g. empirical studies published after 2005 that provided information on their design process, stated their aims and reported their potentially useful findings were graded with the maximum score of 6). If a study met the criteria, a quality score of 1 was added (e.g. studies that met all 6 criteria were graded with a quality rating of 6). Studies with a higher quality score were deemed more likely to provide unbiased and useful information.
Quality assessment was conducted by using Mendeley, which allowed to automatically gather metadata from the studies included as well as to tag each publication with custom keywords.

### 4.1.4 Search, inclusion and exclusion of studies

The studies used in this review were collected by Shmorgun & Lamas (2015) in the context of a PhD thesis, implementing a combination of a systematic review and a scoping study. Key concepts,

main sources and types of evidence were identified in the primary studies, as is done in a scoping study.

The search was conducted across multiple digital libraries and carried out by using the keyword phrases „distributed user interface“ and „distributed user interfaces“. Alterations were avoided due to the extensive amount of results they would produce. Initial publications were selected by browsing through the titles, abstracts and keywords, which resulted in 43 studies, out of which 14 were included in the study.

Further studies were found by forward and backward searching references found in the initially included studies, summing up to 114 publications in general. Studies were excluded based on pre-determined inclusion criteria, which was iteratively complemented or altered.

### 4.1.5 Data extraction and analysis

Data was extracted and analysed from the primary studies by using the conventional content analysis approach (Hsieh & Shannon, 2005). This approach requires researchers to read publications to achieve immersion and a sense of the whole (Tesch, 1990). In the process, codes are derived to capture key thoughts and concepts that appear in the publications. This process is iterative with different thoughts and perspectives expected to arise during each cycle. Codes derived from the publication were sorted into relevant categories. Definitions for each category and code were developed with examples for each code being provide (see Table 2). The data analysis procedure is repeated when necessary, e.g. when browsing studies for concepts that emerged later during research.

Extracting data from publications was done by using two different software tools. Mendeley was used to extract different metadata from the studies, such as:

- Authors
- Type of study
- Abstract
- Keywords

This data was primarily used to assess the quality of the studies included in the review. Coding different concepts and thoughts was done using NVivo – a widely used qualitative data analysis

tool that allowed creating codes and generating reports for each code and pointing out all occurrences connected to a code.

## 4.2 Results

### 4.2.1 Search results

Most publications included in the review were conference proceedings and journals (see Figure 4). Although book excerpts were also present, their amount was considerably smaller. Most journal articles were published in Elsevier's International Journal of Human-Computer Studies and in ACM's Transactions on Computer-Human Interaction. Most conference publications were from various CHI conferences while IEEE, UIST, AVI, EICS and MUM were also present.

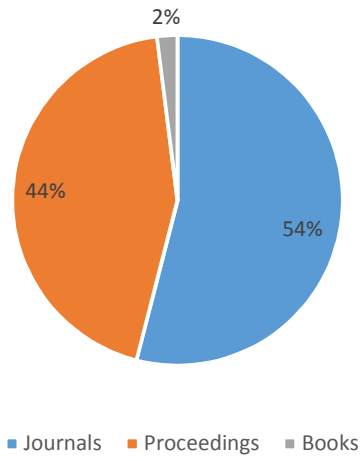


*Figure 4: Publication distribution by type*

The publication years ranged from 1990 to 2015 (see Figure 5). Eight studies were published in between 1990 and 1999, thirty-five studies were published in between 2000 and 2009 and seventy-one publications were published in the current decade.

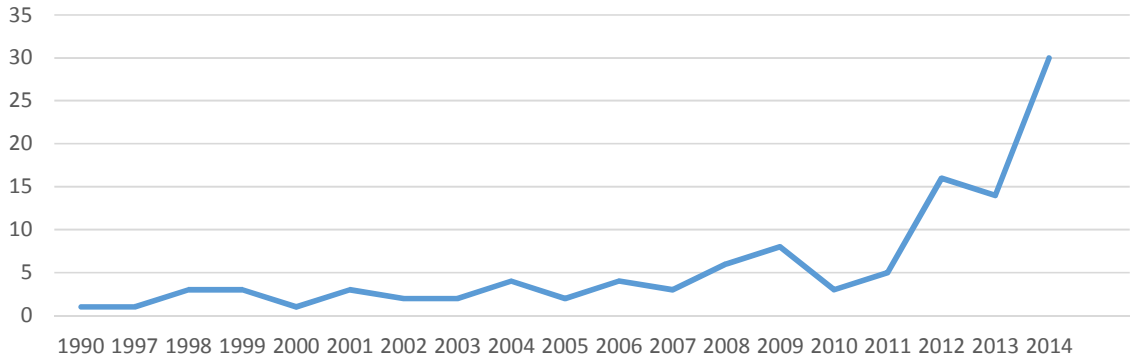


*Figure 5: Publication distribution by year*

On one hand, these statistics show that the topic of distributed user interfaces has been under investigation for the past three decades. However, taking into consideration the major advances in technology that have been taking place during recent years, all publications written before the current decade may be less valuable in terms of the quality input they provide. A noticeable spike in DUI studies took place in 2012 – every consecutive year has seen large amounts of DUI research published. These studies provide interesting insight into how distributed user interfaces have been approached in different eras and technological circumstances, but they may often describe technological constraints that have since been removed. Examples of this situation can be witnessed in publications describing collaboratively editing documents (Knister & Prakash, 1990) or studies describing approaches to collaboratively connect multiple PDAs (Myers, Stiel, & Gargiulo, 1998). Empirical studies were present in all periods, whilst different frameworks (Hutchings & Pierce, 2015) or tools (Paek et al., 2004) for creating distributed user interfaces were more prominent after the year 2000.

### 4.2.2 Quality assessment

All studies were assessed in accordance with a pre-defined criteria, consisting of six items. For each criteria, a weight of 1 was applied for „yes“ and 0 for „no“. The papers could be divided into six categories based on a set of 6 properties, including their goals, clarity, thoroughness, publishing date and research value.

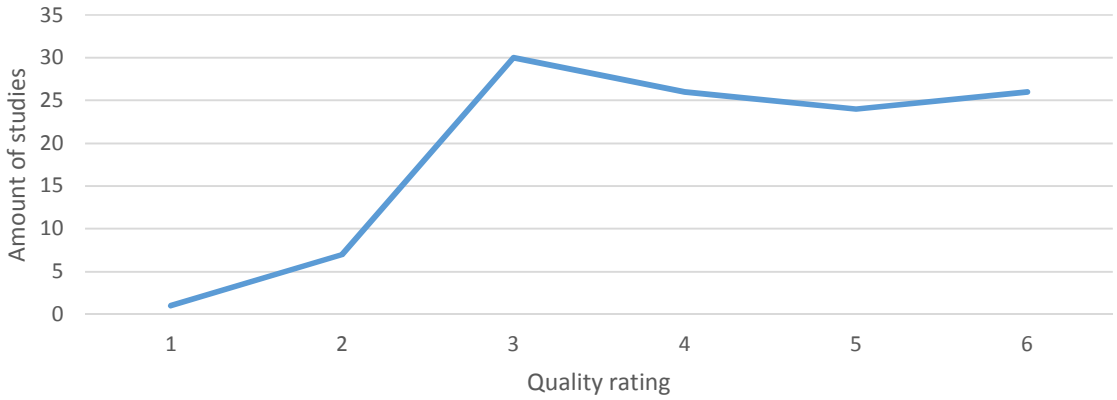


*Figure 6: Quality assessment of selected publications*

Only one paper received a quality assessment score of 1, 7 papers received a quality score of 2 (see Figure 6). As such, eight papers received an under average quality score. These studies were mostly theoretical and vague in describing their research goals, findings and the implications and value of their work.

30 studies met 3 of the 6 pre-defined criteria. These papers mostly included publications published before 2005 that were either too vague in describing their design process or did not provide any visible value for further research. 26 publications were graded with 4 points and 24 with 5 points. 26 papers met all the criteria and were graded with 6. These studies were published during the last decade, focused on empirical research, were clear in their goals and findings and provided clear value for further research.

### 4.2.3 Data analysis results

The initial data analysis resulted in a varied set of different codes, which lead to the need to divide the codes into sub-categories in the following iterations. Each category consisted of multiple codes and their references. During the initial data gathering and analysing iterations more emphasis was put on identifying the primary concepts. The following iterations were done with the goal of supplementing and verifying previously defined codes and categories. Five main categories were defined, each consisting of multiple codes. If a code was identified in less than three different studies, it was omitted from the final results. A table was created based on the codes and categories defined with each code being provided with an example reference.

*Table 2: Categories derived from the literature review*

| Code | Example | References |
|---|---|---|
| **Motivations behind DUI research** | | |
| *Interacting with public displays* | *„Our experimental study concentrates on multiplayer gaming on mobile phones enhanced with a shared large display.“* (Strömberg, Leikas, Suomela, Ikonen, & Heinilä, 2005) | 21 |
| *Creating DUI workspaces* | *„This paper presents a novel approach to support activity-based computing in distributed MDEs, where displays are physically distributed across a large building.“*(Bardram, Bunde-Pedersen, Doryab, & Sørensen, 2009) | 19 |
| *Enabling cross-device data transfer* | *„On a conceptual level the Drag-and-Drop technique allows users to drag data from a mobile device and drop it into a desktop screen and vice versa.“*(Simeone et al., 2013) | 15 |
| *Enhancing the user experience* | *„Connecting shared displays to mobile devices is an obvious way to leverage the best of both worlds, but tight synergy comes only when mobile device users can rely on the ubiquity of shared displays.“*(Paek et al., 2004) | 12 |
| *Encouraging social interactions* | *„Prior work shows that the shared information space created by multiple mobile devices can encourage users to communicate to each other naturally.“*(Huang et al., 2012) | 5 |

| | | |
|---|---|---|
| *Supporting reading on digital devices* | *„Our reading system, United Slates, is based on a collection of moderately sized but highly portable slate devices. We draw inspiration from how paper documents derive important functionality by distributing content across several different sheets that are individually mobile.“*(Chen, Guimbretiere, & Sellen, 2012) | 3 |
| **Tools** | | |
| *Middleware for enabling DUIs* | *„WebSplitter provides a unified XML framework that enables multi-device and multi-user Web browsing. WebSplitter splits a requested Web page and delivers the appropriate partial view of each page to each user, or more accurately to each user's set of devices.“*(Han, Perret, & Naghshineh, 2000) | 23 |
| *Software for prototyping DUIs* | *„Building on what we learned in our interviews and prototype evaluation, we created a tool for the early-stage design and prototyping of cross-device UIs called Damask.“*(Lin & Landay, 2008) | 17 |
| *DUIs for supporting user activities* | *„In this paper, we present the initial explorations of the ActivityDesk system, an interactive desk that supports multi-device configuration work and workspace aggregation into a personal ad-hoc smart space for knowledge workers.“*(Houben & Bardram, 2013) | 17 |
| | | |

| | | |
|---|---|---|
| **Collaboration** | | |
| *Facilitating collaborative interactions* | *„This paper presents SharedViews, a computer-based collaborative environment aimed to support collocated team brainstorming session during the post-hoc review of emergency plans.“*(Díez, Tena, Romero-Gomez, Díaz, & Aedo, 2014) | 47 |
| **Constraints of creating DUIs** | | |
| *Privacy and security* | *„The public UI sets limitations for application developers as well. We cannot allow developers to freely deploy native applications in the control PCs of the public displays, as they would pose a serious security and possibly a performance issue to our system.“*(Hosio, Jurmu, Kukka, Riekki, & Ojala, 2010) | 8 |
| *Technology* | *„Unfortunately, the current state of hardware development prevents a study with the envisioned hardware. Accordingly, we could not test features that depend on a larger, curved display, among them rotating menus and interaction of the posterior of the arm.”* (von Zadow, Büschel, Langner, & Dachselt, 2014) | 5 |
| *User adoption* | *„The project initially operated in a busy lab, in which the display proved to be no more than a curiosity since it could not be used for long periods of time and offered* | 3 |

| | | |
|---|---|---|
| | *little integration with other devices.“* (Gabriel et al., 2006) | |

### 4.2.4 DUI research motivations

The primary studies included both empirical research describing the creation of a technological artefact, as well as theoretical research providing insight into certain topics. Most of the papers provided a rationale for why the research was carried out. Rationale behind conducting DUI research was extracted from 71 publications.

The most numerous amount of publications – 21 of 71 – touched upon the subject of interacting with shared public displays. These publications included both applications requiring interacting with an external shared display such as Wordster (Luojus et al., 2013), but also studies that proposed interaction techniques to be used in interacting with shared displays (Machuca, Chinthammit, Yang, & Duh, 2014).

19 studies touched upon the subject of enabling multi-display environments with distributed user interfaces in work environments. A majority of these publications were empirical studies that touched upon the creation of tools that enable DUI workspaces, such as the iRoom (Gabriel et al., 2006) and a few touched upon the subject as a potential use-case of the tool or application they proposed (Wigdor, Jiang, Forlines, Borkin, & Shen, 2009).

27 publications described interactions between multiple portable devices – 15 of these studies focused on transferring data between devices (Hinckley, Ramos, Guimbretiere, Baudisch, & Smith, 2004) and 12 described connecting multiple devices together to enhance the user experience, e.g. by expanding the available screen space of portable devices (Paek et al., 2004).

A considerably lesser amount of publications stated that the main motivation behind conducting DUI research was to encourage and improve social interactions (Huang et al., 2012). An equal amount of publications strived to improve the reading experience on digital devices, either by proposing interaction techniques for it or by proposing enhanced e-reading applications that leverage distributed user interfaces (Girouard, Tarun, & Vertegaal, 2012).

### 4.2.5 Tools

57 publications described tools that either enable the usage and implementation of distributed user interfaces or provide designers with the means to prototype distributed user interfaces.

Out of the 30 publications that focused on creating DUIs, 23 proposed different approaches, frameworks or methodologies for creating DUIs, e.g. frameworks for enabling the transition of web content across multiple displays (Johanson, Ponnekanti, Sengupta, & Fox, 2001). 17 studies proposed software tools for building applications that support distributed UIs (Knister & Prakash, 1990).

17 studies proposed tools that enabled the implementation of distributed user interfaces, both in public settings (Lucero, Jokela, Palin, Aaltonen, & Nikara, 2012) as well as private work (Houben & Bardram, 2013) or leisure (Rädle, Jetter, Marquardt, Reiterer, & Rogers, 2014) environments.

### 4.2.6 Collaboration

The topic of enabling collaborative interactions was mentioned in 41 publications. 31 of them touched upon the subject of collaborative interactions, whilst 16 proposed tools that enable collaboration in groups of people.

Most publications that touched upon the subject of collaborative interactions did so by mentioning it as a possible use of their proposed tool (Pirchheim, Waldner, & Schmalstieg, 2009) or by touching upon the subject in their discussion (Lim, Choi, & Lee, 2013).

16 studies described tools for enabling collaborative interactions, both by enabling interacting with shared content (Tandler, Prante, Müller-Tomfelde, Streitz, & Steinmetz, 2001), as well as enabling collaborative working (Knister & Prakash, 1990).

### 4.2.7 Constraints of creating DUIs

Out of the 114 studies included in the review, 22 mentioned different constraints that can influence the implementation and/or development of distributed user interfaces. These constraints were only present in studies that described the development of a tool or an application, since a majority of these studies also presented a user study of their proposed solution. Many of these publications were too focused on evaluating the usability of their product, hence bringing out constraints that could not be generalised as a constraint of DUIs in general. However, a few common themes emerged across multiple publications. These could be seen as constraints related to enabling and

creating distributed user interfaces in general and were grouped into three categories. 8 studies mentioned security and privacy related issues as the main constraint of enabling distributed user interfaces, e.g. making sure sensitive data displayed on shared public displays is visible only to those with the appropriate privileges (Bardram et al., 2009). 5 publications described technological constraints as the main barrier in implementing their proposed solutions. Most of these publications proposed hypothetical solutions that were not fully implemented due to a lack of existing technologies that could assist in realising these solutions (von Zadow et al., 2014) or were implemented with some drawbacks due to technological constraints (Tandler et al., 2001).

A small amount of publications also proposed user adoption as the main drawback of enabling distributed user interfaces. 3 publications stated that enabling DUIs is challenging due to users mainly seeing their proposed applications as curiosities rather than useful tools (Gabriel et al., 2006).

### 4.2.8 DUI interaction techniques

19 publications proposed different interaction techniques for distributed user interfaces. Most of these patterns were unique and mentioned only in a single occurrence, with "Pick, drag & drop" being the only exception (Rekimoto, 1998), as it was mentioned 6 times overall. 5 different patterns for designing e-reading environments were proposed with the aim of making e-reading environments more habitual to the user (Girouard et al., 2012).

## 4.3 Discussion

The amount of literature published on the subject of distributed user interfaces has been growing rapidly. As illustrated by Figure 5, the amount of studies that were deemed suitable for this review has grown from a single publication in 1990 to thirty publications in 2014 (see Figure 5).

Most publications analysed in the course of the review proposed a rationale behind the research being conducted. As shown in Table 1, many of these motivations may overlap at times. For example, developing applications or proposing UI design approaches for interacting with shared displays can be done with the goal of creating multi-display work environments (Myers et al., 1998) or to provide interactive public displays in urban environments (Hosio et al., 2010), such as public information terminals that can be accessed with a smartphone.

Multi-device usage was another common concept present in the publications analysed. Many studies proposed techniques for transferring data from one device to another (Gabriel et al., 2006)

or combining the user interfaces of multiple smaller devices (Strömberg et al., 2005), thus allowing users to take advantage of the benefits of each device and to minimise their limitations. There were multiple concepts present that were seldom mentioned. Still, many of these concepts stood out as their results may be beneficial for different target groups. Examples of these concepts include enabling interaction with non-technological objects (Yeo, Nanayakkara, & Ransiri, 2013) or enabling distributed multi-display systems that support activity-based computing across a large environment (Bardram et al., 2009).

Although the amount of published DUI literature has been growing at a steady rate, most studies still revolve around subtler motivations behind employing distributed user interfaces, such as simply expanding the user interface of an application across multiple displays with the goal of expanding the available screen space. Implementing distributed user interfaces in public environments or enabling distributed multi-display environments across large areas has not yet been extensively covered and can be seen as a potential future development in the field of DUIs. Among the less mentioned motivations behind enabling DUIs was the idea of aiding the disabled, specifically those with hearing or visual impairments (Yeo et al., 2013).

Although multiple frameworks for creating distributed user interfaces were analysed, many of them were proposed in the early years of the 21st century. Due to this, lots of them were limited by constraints posed by technological shortfalls of the time and are not relevant anymore. Most publications that presented tools that enable the usage of distributed user interfaces were published during the past ten years. However, rather than focusing on expanding the capabilities of these tools, more emphasis was put on making these tools easy to implement.

Collaboration was a notable concept present in the publications analysed. There was a notable interest in enhancing collaboration in working environments, where multiple team members have to use their own devices in connection with a shared display space. Less attention was given to analysing how distributed user interfaces can enhance social collaboration in public spaces or in collaborative applications, such as games that require a sufficient amount of teamwork. Although the concept of collaborative interactions was heavily present in the literature analysed, approaching it from other perspectives should be attempted in future research.

Most empirical publications that presented a tool or software started out as DUI projects from the beginning. Against expectations, there was a considerable shortage of publications that described the re-designing process of an existing user interface from being limited to a single display to being

distributed. Most distributed user interface studies were not user-centric. The few that conducted user studies often did so without fully implementing the results of the study in their prototype or planned to conduct user studies in future work. Around half of the publications analysed user-tested their prototypes after developing them. In some cases, user-testing was mentioned as future work.

Different DUI interaction techniques were proposed in the publications. These techniques rarely overlapped in different publications, as each publication preferred to define its own approach to designing distributed user interfaces rather than building upon and developing an existing approach. Out of the 21 proposed techniques, one was mentioned more than three times in different publications and four were mentioned two times across multiple studies. Many of these interaction techniques were inherently similar in their approaches and purposes. Employing interaction techniques in practice should be done due to the concept of distributed user interfaces not being defined clearly, but that requires the existence of previously evaluated techniques.

Studies analysing the effects, possibilities and constraints of enabling distributed user interfaces were rare. Although some publications offered insight into how enabling DUIs can enhance social interactions (Sørensen & Kjeldskov, 2012) or comfort in navigating (Chen, Guimbretière, & Sellen, 2013), most studies revolved around describing proposed DUI projects. Further research into the possibilities and constraints of distributed user interfaces would benefit the field in general. Manu publications that had conducted user studies reported different constraints they had come across. These findings often revolved around aesthetic issues or problems inherent to the concept of the application. As such, they could not be generalised and seen as overall constraints of distributed user interfaces.

A major proportion of the publications analysed aimed to enable multi-display environments, where users can collaboratively interact with shared displays, either for work purposes or in more casual settings. Multiple publications described an office meeting as the primary scenario in which their proposed solution would be used. Enabling interactions with public information screens or designing games that span across multiple displays were also mentioned in the studies analysed.

Many motivations behind DUI research were mentioned seldom in the selected studies, but may have a lot of potential for further development. These motivations include using distributed user interfaces to aid the disabled (Yeo et al., 2013), raising communal awareness or enhancing smart objects capabilities (Zhao & Wang, 2011).

This leads to the conclusion that most research in the field of distributed user interfaces is focused on technical topics, such as proposing applications that employ distributed user interfaces. However, more work in the field of defining different interaction techniques for creating distributed user interfaces or improving existing design patterns should be done. This would aim to raise awareness about the different techniques available as well as to help researchers tackle common design challenges.

Collaboration was predominantly the most prominent concept present in the publications analysed. On multiple occasions, collaborative interactions were touched upon as possible scenarios where a proposed solution would be used. An equally large amount of studies revolved around designing tools that enable collaboration between users.

Enabling multi-device environments was another dominant theme present in the research analysed. Multi-device environments were proposed both for work purposes as well as more casual settings. The reasoning behind designing MDEs varied from improving the general workflow to simply expanding the screen space of single devices by combining their user interfaces.

There were few publications that analysed the constraints and benefits of enabling distributed user interfaces. This insight might prove valuable to researchers and designers carrying out DUI projects, which is why they should be covered further in future research.

## 4.4 Closing remarks

This literature review aimed to analyse both recent and past publications in the field of distributed user interfaces with the aim of understanding what are the main concepts present in DUI research and what are the main motivations behind conducting it.

The results of the review revealed that the amount of DUI research has been growing in a rapid pace over the past years. However, most publications are focused on exemplary applications that employ distributed user interfaces and little research is done on distributing existing user interfaces across multiple devices. A considerable amount of publications revolves around enabling interactions with shared displays with the goal of supporting collaboration either in social or work settings. Similarly, many publications propose approaches for enabling multi-device environments, either through providing means for data transfer between portable devices or by expanding the limited UI space available in portable media devices.

Publications that propose interaction techniques for DUIs are rare with similar concepts often being defined under different names. More work should be done in improving existing approaches rather than reinventing them under different labels.

Although the amount of DUI research being published has grown in the recent years, the field has not yet fully matured. Although multiple interaction techniques have been defined, many of them are inherently similar and have not been grouped into design libraries. Similarly, a predominant amount of DUI literature revolves around enabling distributed user interfaces in the same context. Further research should also be done in enabling DUIs in other scenarios and in distributing already existing user interfaces.

# 5 Choosing the right tools for a literature review

The expansion of evidence-based research led to an increasingly varied selection of literature reviewing methodologies. Since most of these methodologies are developed for different end-goals, they may vary in their work methods. However, their main approaches to reviewing literature remain inherently similar, due to which they can easily be analysed using the same framework. The framework proposed by Grant & Booth (2009) divides a literature reviewing methodology into four different stand-alone stages – search, analysis, appraisal and synthesis. By grouping all literature analysis methodologies proposed by Grant & Booth (2009) into a spreadsheet and comparing them, it becomes increasingly relevant that most literature reviewing methodologies differentiate on a conceptual level. The differences between methodologies are perfunctory and mostly reflect in how data is analysed and presented.

This lack of differences between methodologies was also evident in the case study. Although some elements were inherent to a systematised (or a systematic) review, such as generating a review protocol, most methods used were seemingly similarly represented in other methodologies. This may somewhat be attributed to the nature of a systematised review, which allows omitting different phases and methods in case of need.

This inherent similarity in approaches is also visible in different qualitative content analysis methodologies. Whilst there are certain differences in terms of specific work methods, all three approaches proposed by Shannon & Hsieh (2005) focus on coding various concepts from qualitative data and attempting to define them.

The similarity of different literature reviewing methodologies reflects on the specifics of software available for conducting literature reviews. Most widely used literature reviewing software is suitable for most methodologies, regardless of their work methods. This comes from the fact that the majority of literature reviewing software is focused mainly on the data analysis and synthesis stages without offering any functionality in terms of constructing search queries, carrying out quality assessments, etc. Due to this, a hypothetical assumption was made that in order to reach the best results, several tools should be employed for each phase of the literature review.

The case study conducted to evaluate the usefulness of employing specific software in literature reviews disproved this hypothesis. Choosing the tool to conduct the case study was not difficult,

as most technologies were inherently similar in their functionality. Hence, the final choice was made by choosing the software that met three criteria:

- It is currently supported and new versions are continuously being developed – this was necessary to guarantee full functionality and to access customer support if necessary (e.g. when encountering technical issues);
- It has a sufficient amount of documentation and help materials available – this was needed to guarantee that guidelines existed on how to use the software;
- It is available on both Windows and Mac OS X operating systems.

Based on all these criteria, NVivo was chosen as the most suitable tool to carry out the review. Although the purpose of NVivo is to allow researchers to analyse data objects and code them, this could also be expanded to other stages of the literature review. For example, the quality assessment was initially planned to be conducted by using a form tool, such as Google Forms. However, it soon became obvious that the coding system in NVivo could also be used to conduct the quality assessment. This was done simply by coding each publication with the quality assessment criteria it possessed.

Discussions with other researchers revealed that the common approach to documenting data analysis results is to use an Excel spreadsheet. This can make the process of extracting data in the synthesis phase cumbersome, as connecting each code to all occurrences in different papers is difficult. NVivo helps researchers tackle this issue by generating reports for each code. These reports contain direct references to every place in a publication from where a code was derived.

This functionality enabled analysing how often a code occurred in different publications as well as to determine the content behind each code. Whereas inserting every occurrence of a code into a spreadsheet would be a cumbersome task, coding in NVivo proved to be seamless and convenient.

When describing various literature reviewing methodologies, different work methods and their requirements were listed. Although some of these requirements were simple, propositions were made on which software would be best suitable to use to address them. Using a vast amount of different applications resulted in making the reviewing process more burdening and time consuming. The hypothetical statement that employing a wide range of tools in the process of a literature review may improve its quality did not take into account the time-consuming nature of literature reviews. Although the exact time it takes to conduct a thorough literature review depends

on multiple factors, it may range from weeks to months. Employing more than two software solutions may burden the researcher rather than assist in conducting the research.

In the case study, NVivo was employed both on Windows as well as Mac OS X operating systems. The applications differed in terms of the user interface, functionality, as well as reliability. While the Windows application was designed similarly to Office 365, the user interface on the OS X application stood out as being more unique. However, the OS X application proved to be slow and prone to crashes, whereas the Windows application worked without any performance issues. Another interesting difference was that the Windows application reminded users to save their work every fifteen minutes, had they not done so.

Another tool employed in the review was a reference manager. A reference manager was employed due to the fact that NVivo lacks functionality for extracting metadata from publications. Most publications were simply named after the file names without proving any insight into the title or the authors in the list view of all the publications. This triggered the need for a tool that was able to extract and possibly complement metadata from the studies.

Mendeley was chosen as the most appropriate tool. This was due to the fact that the software was available on both Windows as well as OS X operating systems and its libraries were stored online. This meant that the studies and all their annotations were accessible from all devices. Additionally, Mendeley provided access to the Mendeley catalogue, which allows researchers to extract metadata from Mendeley's database.

Figure 7 illustrates how different tools can be employed to assist different literature reviewing procedures (see Figure 7). Each literature reviewing approach was mapped against different procedures that can be employed. These procedures were marked with the tools that can be used to carry them out. Only reference management and qualitative data analysis tools were used in the figure, since other tools (e.g. CmapTools) can mostly be used for a single procedure.

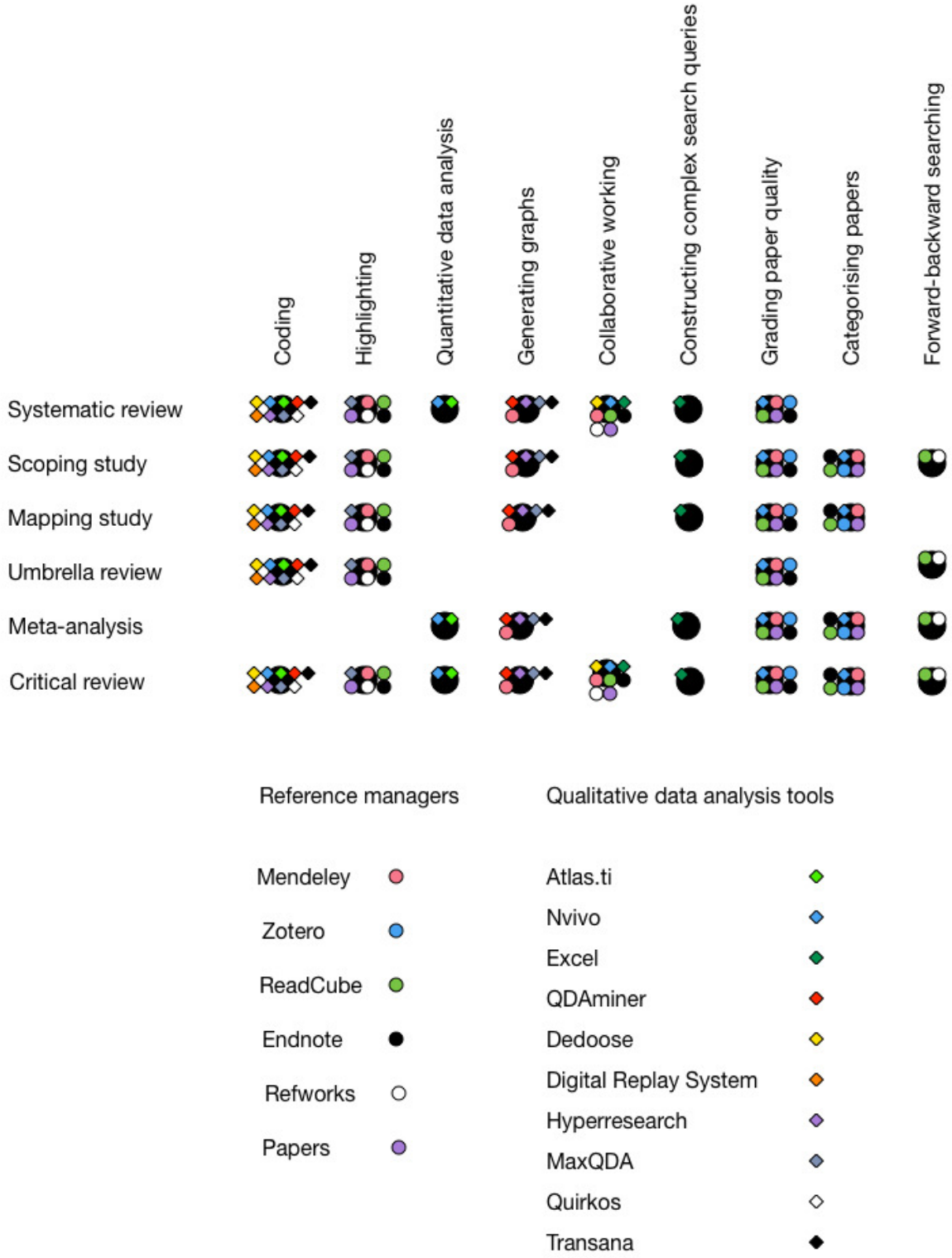


*Figure 7: Overview of the tools that can be used for different literature reviewing procedures*

# 6 Conclusion

Literature reviews are an essential part of conducting research at any level and are often seen as a fundamental aspect of doing research. Reviewing existing literature on a topic can help researchers place the relevance of their own research into a larger context of what has already been done, helping them avoid duplicating research as well as to discover what remains to be done in the field. Conducting literature reviews can be done using various approaches, many of which have formally been defined as methodologies. Each literature reviewing methodology provides researchers with a set of work methods that can be employed to carry out the review. Although most literature reviews vary in their exact work methods, they can similarly be analysed through a four-dimensional framework. This framework, proposed by Grant & Booth, states that all literature reviewing methodologies deal with searching for literature, determining its relevance, analysing it by extracting data and synthesising the collected data.

Grant & Booth (2009) proposed fourteen different literature reviewing methodologies, based on both scoping literary studies as well as practical experience. These methodologies were mapped against the previously proposed framework and grouped into a table. This table was extended by complementing it with the work methods each review type employs and the software that can be used to assist in carrying out these methods (see Appendix 1).

An analysis of literature reviewing methodologies showed that most approaches differentiate on a perfunctory level with differences appearing only in how data is analysed and presented. This trend is also apparent in the extended table (see Appendix 1) – different trends and patterns could be seen in different literature reviewing methodologies.

As reviewing literature has played a pivotal role in research, different software has been proposed to assist conducting literature reviews. While some applications are not initially defined as tools for conducting literature reviews, they can still be used in the process. Other applications are created implicitly to assist in conducting literature reviews. These applications vary in terms of functionality and complexity, but are identical in their end-goals. Most of them also share a common shortcoming, since they mostly focus on conducting the analysis phase and assisting in the synthesis phase of the review.

To evaluate the effect of employing these tools in a literature reviewing process, a case study was carried out. This case study encompassed a literature review in the field of distributed user interfaces. The two primary tools used in the process were NVivo and Mendeley.

Proposing software before conducting the case study was done in „the more the merrier“ approach, proposing different tools for each requirement when possible. The effectiveness of this approach was disproved in the case study, as it turned out that employing a wide variety of tools may hinder and impede the reviewing process.

However, employing literature reviewing software was beneficial. Using NVivo to code publications hastened the process of reviewing publications in comparison to using a spreadsheet. It also allowed analysing codes, displaying all references and occurrences of a code in all the publications.

The amount of approaches to conducting literature reviews as well as the diversity of software available for conducting them is vast. The selected reviewing methodology is not the primary factor in choosing the correct software. Although some methodologies pose special requirements (such as meta-analysis requiring quantitative data analysis tools), most literature reviewing tools can be employed regardless of which reviewing approach is used. Thus, choosing the correct software mainly depends on other factors, such as how many functions does it provide (e.g. cloud-based storage, generating coding reports etc).

# 7 Kokkuvõte

Kirjandusülevaadete läbiviimine asub kesksel kohal mitmetes teadustöödes. Selle läbiviimine aitab saada ülevaadet uuritavast teadusvaldkonnast, kaardistada senise teadustöö poolt katmata jäänud alad või anda hinnang senise teadustöö tugevustele ning nõrkustele.

Kirjandusülevaate läbiviimine on põhjalik ning vaevanõudev protsess, mille kvaliteedist võib sõltuda edasise teadustöö kvaliteet (Levy & Ellis, 2006). Kirjandusülevaadete läbiviimiseks on võimalik rakendada erinevaid metoodikaid – kuigi kõnealused lähenemisviisid võivad jagada sama lõpp-eesmärki, võivad nad erineda meetodite poolest, millega koguvad, analüüsivad ning sünteesivad publikatsioone (Grant & Booth, 2009). See võimaldab kirjeldada kirjandusülevaadete andmise metoodikaid läbi SALSA raamistiku, kirjeldades iga metoodika puhul, kuidas publikatsioone kogutakse, nende kvaliteeti hinnatakse, neist andmeid kogutakse ning neid andmeid esitletakse.

Kuigi praktikas rakendatakse erinevaid metoodikaid, ei kirjeldata sageli detailselt rakendatud töömeetodeid. See tekitab probleemse olukorra, kus kirjandusülevaate läbiviijad peavad tuletama erinevate metoodikate poolt nõutud samme olemasolevatest publikatsioonidest. See infopuudus erinevate metoodikate poolt rakendatavate töömeetodite osas muudab sobivate tööriistade valimise keerukaks.

Grant & Booth on kaardistanud neliteist kirjandusülevaadete andmise metoodikat. Kandes kõnealused metoodikad tabelisse (vt Lisa 1) ning kirjeldades kõiki läbi SALSA raamistiku, järeldub, et valdav osa kirjandusülevaadete metoodikate vahelisi erinevusi on pinnapealsed. Põhiosa erinevusi esineb viisides, kuidas andmeid analüüsitakse ning esitletakse.

Kirjandusülevaadete läbiviimise toetamiseks on arendatud erinevaid tarkvaralisi lahendusi. Kõnealused lahendused erinevad pakutava funktsionaalsuse mitmekesisuse osas, kuid jagavad valdavalt samu põhifunktsioone – võimaldada kasutajatel viia läbi kvalitatiivset andmeanalüüsi, kodeerides dokumente.

Analüüsimaks, kuidas vastava tarkvara rakendamine hõlbustab kirjandusülevaadete andmist, esitati juhtumiuuring, viies läbi kirjandusülevaade hajutatud kasutajaliideste valdkonnas. Antud kirjandusülevaadet toetati põhiliselt NVivo ning Mendeley abil.

Juhtumiuuringut läbi viies lähtuti hüpoteesist, mille kohaselt on kirjandusülevaates rakendavate tööriistade arv võrdelises seoses töö kvaliteediga. Juhtumiuuringust selgus aga vastupidine –

rohkete tööriistade rakendamine mõjus koormavana ning ei parandanud üldist töökvaliteeti. Otstarbekas oli aga vaid kirjandusülevaadete läbiviimist toetavate rakenduste kasutamine, mis võimaldas publikatsioone kodeerida ning kodeeritud mõisteid hiljem analüüsida.

Kirjandusülevaadete läbiviimise metoodikaid ning neid toetavaid tarkvarasid on palju. Metoodika, mida rakendatakse, ei saa pidada määravaks faktoriks tarkvara valimisel, mille abil ülevaadet läbi viia. Valdav osa tööriistu on oma funktsionaalsue poolest sarnased ning võimaldavad kasutamist olenemata rakendatavast töömetoodikast.

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# Appendix 1. Table of literature reviewing methodologies, requirements and tools

*Table 3: Table of literature reviewing methodologies, requirements and tools*

| Methodology | Sub-types | Description | Methods used | | | | Requirements | Tools |
|---|---|---|---|---|---|---|---|---|
| | | | Search | Appraisal | Synthesis | Analysis | | |
| Systematic review | Rapid review, Systematised review, Systematic search & review | A well defined literature reviewing methodology that aims to identify, analyse and interpret all available evidence related to a certain research question without being biased. Very thorough, requires lots of effort and the involvement of multiple researchers. | Must define the need for the research and evaluate previously written reviews (should they exist), after which the research questions should be defined (which should have an effect on the current practices and reseach, either by altering it or complementing it). A reviewing protocol is made to ensure that the reviewing process is not biased. A | Defines an inclusion-exclusion criteria, compares it to all primary studies, initially based on the title and abstract - full papers should only be browsed when needed or in the follow-up iterations. Creates a list of excluded literature and provides information on why each paper was excluded. The appraisal process is iterative with changes in the process being made in between | A form should be designed to extract data from the primary studies, which should aim to gather all information related to answering the research question (including both general data about the publication as well as custom data related to the research question). Requires cross referencing data between researchers. | What is known; recommendations for practice. What remains unknown; uncertainty around findings, recommendations for future research. All data should be presented as a stand-alone report that must be peer reviewed. | Data extraction through forms (must allow data-storage and later analysis of quantitative statistics, such as the number of papers), tabulating extracted information (both quantitative as well as qualitative), analysing confidence intervals and mean values for quantitative data, generating forest plots, text editing & | Google Docs (spreadsheets), SPSS or PSPP, Evidence Partners Forest Plot generator, Text editing software with sharing capabilities, Mendeley, Nvivo, Cmaptools |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | search strategy is defined, focusing on the facets of the research question and it's possible synonyms, abbreviations and alternative spellings. | the iterations if required. | Qualitative data is descriptively summarised, quantitative data can be analysed using statistical techniques such as the meta-analysis methodology. Tabular forms should be employed when necessary. | | sharing collaborative documents, constructing complex search queries | |
| Mapping Study | N/A | A means to create a classification scheme and structure a field of interest. Provides a structure of the type of research reports and results that have so far been published by presenting them in a visual | Begins with defining the research question, which helps address the scope of the planned study, which has to be broad enough for the subtle work methods of a mapping study to be able to provide answers to them. All facets of the | Works by defining a specific inclusion-exclusion criteria and pairing it with the primary studies. The criteria is directly derived from the research question. | Carried out by systematic keywording, which aims to generate a classification scheme and to organise the selected publications according to their content - first, abstracts are browsed for concepts, after which keywords from different | All papers are grouped to categories, providing a short rationale on why each paper belongs in it's category. Frequencies are visualised and conclusions are drawn based upon them on which categories are more emphasised and where the gaps in | Marking papers (based on exclusion-inclusion criteria), coding and categorising abstracts, dividing papers into research facets, storing data about each paper, generating frequency tables, text editing | Nvivo, Mendeley, Microsoft Excel (both storing data as wel as generating frequency tables), Word |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | summary. Is superficial in nature, best used to specify gaps in existing literature by providing a basis for an informed decision about whether an in-depth review should be undertaken. | research question should be included in the search queries - as the aim is to be as broad as possible, different variations should be employed. | | papers are combined so that an understanding about the nature and contribution of the reserach is gained. Through this, categories are coded. | current research may be. | | |
| Scoping Study | N/A | Similar to a mapping study in it's end-goals, aims to rapidly map the key concepts that underpin a research area and the main sources and types of evidence available. Usually carried out as a stand-alone project, the breadth and depth of the study depend on the purpose of the review. | Defines the research question, which may guide the way search strategies are built. Searching for primary studies is done in a broad manner, while taking care not to generate an unmanageably large set of papers. Complex search queries should be implemented | Works by defining a criteria for including and excluding irrelevant studies. This criteria may be re-evaluated during the appraisal process due to increasing familiarity with the subject. Most conclusions must be drawn from the abstract alone, with browsing the full paper only when necessary. | Mostly done by charting - a data analysis method that includes analysing the studies and sorting out different key issues and themes. Charted data should include both general information about the publication as well as contextual information | Differentiates itself from most other literature reviewing methodologies by giving an overview of both included as well as excluded literature. | Searching the references of primary studies, constructing search queries, comparing all papers to an inclusion criteria, categorising them accordingly, coding key issues and themes, storing coding data, text editing | Nvivo, Mendeley, Cmaptools, Microsoft Office (Word, Excel) |

| | | | | | | | | |
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| | | | with revisions made when necessary. | | about the study. | | | |
| Umbrella review | N/A | An overarching literature review that aims to review other reviews. Allows researchers to address a broad scope of issues related to a particular research topic and is usually undertaken to summarise evidence from more than one synthesis of existing research evidence. | Defines both the research question as well as the background of the area being researched. A research protocol is created that aims to define the exact strategy for locating research relevant to the review. Can mainly be divided into three parts - identifying keywords, constructing search filters and searching the re reference lists of all | Defines a multidimensional inclusion criteria, assesses all studies for methodological quality. A score weight is set for each criteria and then applied to each publication. Papers that surpass a certian level are included in the study. | Although there is a lack of any official guidelines for extracting data from the primary studies, forms have been created for umbrella review data extraction that can be employed. A tabular presentation of findings is generated, where the overall effect estimates from the reviews are presented. | Creates a review document that includes generic data about the publications as well as information about the conclusions of the review. | Comparing papers to an inclusion criteria, storing data about publications (e.g. contextual data), searching reference lists, extracting data from publications, presenting data in a tabular format. | Nvivo, Mendeley, Microsoft Office (Word, Excel) |

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| | | | included reviews. | | | | | |
| Meta-analysis | N/A | Used to combine findings from previously conducted independent studies. Mostly used to combine data from different quantitative stadies, but can also be used as part of a systematic review that aims to analyse publications dealing with quantitative data. | Aims to find highly qualitable source studies, as they directly influence the quality of the meta-analysis. Searching must be conducted on multiple electronic databases, and the strategy should be defined as a sequence of requirements - e.g. to find papers that contain specified terms. | Defines a set of inclusion and exclusion criteria. Similarly to an umbrella review, a quality score system can be defined with papers scoring lower ratings being excluded from the final review. | Defined a coding sheet and lists the variables that should be extracted from each study and how they should be coded. Defines effect sizes and analyses findings using appropriate statistical methods. | Mainly relies on visually presenting findings through different graphs. Most commonly presents findings with a forest plot, which visualises effect size estimates and confidence intervals for each study included in the review. | Analysing quantitative data, creating forest plots and other charts, text editing, constructing search queries and browsing through reference lists | SPSS or PSPP, R (programming language), Nvivo, Mendeley, Microsoft Word |

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| Critical review | Overview, Systematic search and review | A detailed commentary and analysis of literature, can be conducted as a stand-alone research project or as a preparation for a systematic literature review. | No official guidelines, but usually begun with defining both the research questions, the objective of the research and the rationale of the review. | Aims to evaluate the contribution of each primary study. | Presents the findings of each reviewed publication in line with the aim of the research. Visual methods such as graphs are used if appropriate and necessary. Gaps in data should be explained. All primary studies must be analysed in full length. | Provides a discussion and interprets the findings. Includes the overall strengths and weaknesses of the findings and speculates on their significance in further research in the field. | Less official requirements, most can be covered by a reference and bibliography management tool with some simple data presenting possibilities | Nvivo, Microsoft Word, Statistical software for presenting quantitative data about papers |
| *Qualitative Evidence Sytnhesis* | *N/A* | *A methodology for integrating findings from various qualitative studies. Is still in it's infancy, specific work methods have yet been defined.* | N/A | | | | | |

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| *State of the art review* | *N/A* | *Aims to address current matters in contrast to the retrospective approaches of other literature reviewing methodologies. May offer new insight or perpsctives and find new possible areas of research. More suitable to research new to their fields.* | N/A |
| *Mixed methods review* | *N/A* | *Refers to any combination of different methods, where at least one of the methods is a literature review, most often a systematic review.* | N/A |
| **Content analysis methods** | | | |

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| Conven-tional content analysis | Generally used with a studies aimed to describe a phenomenon, useful when existing literature is limited. Existing categories are avoided, allowing the codes to generate during the analysis procedure. Codes are divided into categories based on their relations, after which each category will be defined. Can be useful when extracting categorie by gathering data directly, but can make it difficult to develop a complete understanding of the context. |
| Directed content analysis | Used when existing theory is incomplete or would benefit from futher description. More structured than it's conventional counterpart, research is begun by identifying key concepts, which are then defined using existing theory. The data gathered may support or unsupport existing theory. Mainly stands out in it's ability to extend existing research. |
| Summative content analysis | Usually starts with identifying certain words in text with the aim of understanding the context they are used in. Data analysis begins by searching for occurences of the defined words, after which frequency counts for each word are presented. Is unobtrusive and can give insight into how certain terms are actually used, but offers little information on the broader picture. |