

# Making sense of diseases in medication reconciliation

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**Abstract** Patients are most at risk during transitions in care across settings and providers. The communication and reconciliation of an accurate medication list throughout the care continuum are essential in the reduction in transition-related adverse drug events. Most current research focuses on the outcomes of reconciliation interventions, yet not on the clinician's perspective. We aimed to explore clinicians' cognitive processes and heuristics of making sense of patients' disease histories. We used the affinity diagram method to simulate real-life medication reconciliation with 24 clinicians. The participants were given paper cards with diseases and medications representing a real case from an anesthesiology department. The task was to sort the cards in a set that made sense to the clinician. The experiment was video-recorded, and the data were analyzed using a quantitative spatial analysis technique. Levene's test for equality of variance showed that 79% of the 24 participants arranged the diseases along a straight line ( $p < 0.001$ ). With only few exceptions, the diseases were arranged along the line in a fixed order, from cardiac conditions to depression (Friedman's  $\chi^2(44) = 291.9$ ,  $p < 0.001$ ). We learn from this study that although clinicians employ a variety of coping strategies while reconciling patients' medical histories, there are common reconciliation strategies. Understanding heuristics and the mental models

clinicians have for the reconciliation process may help to develop and implement methods and tools to promote safety research and practice.

**Keywords** Medication reconciliation · Medical expertise · Medical cognition · Diagnostic reasoning · Patient safety · Card-sorting · Affinity diagram

## 1 Introduction

Medication failures are some of the most frequent causes of preventable harm in health care (Budnitz et al. 2006; Cornish et al. 2005). Medication reconciliation (MR) is the process of constructing a patient's medication history within the context of care transitions. Clinicians deal with MR constantly during patient care. Several obstacles to comprehensive reconciliation are complex drug interactions, ambiguous findings, and unclear or missing information. Unintentional medication discrepancies and failures are common on both hospital admission and discharge, and many recognize MR as a process vulnerable to failure (Brady et al. 2009; Clay et al. 2008; Frei et al. 2009; Gandara et al. 2009; Jylha and Saranto, 2008; Miller et al. 2008; Pippins et al. 2008; Wong et al. 2008).

In 2005, the Joint Commission defined MR as a national patient safety goal (JCAHO 2005). Since then, many organizations have developed and implemented procedures to improve MR, such as forms, pharmacist supervision (Boockvar et al. 2006; Coffey et al. 2009; Hayes et al. 2007; Manning et al. 2007; Pronovost et al. 2003; Walker et al. 2009; Weingart et al. 2007), and information technology interventions (Agrawal 2009; Kramer et al. 2007; Poon et al. 2006; Schnipper et al. 2009; Turchin et al. 2008). What remains largely unstudied is the cognitive

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process of clinicians when reconciling patient medication lists. What is MR in the clinician's view? What defines the act of reconciling medications? What cognitive strategies (or heuristics) do physicians use to make sense of the incomplete information provided to them, to evaluate data as complete or incomplete, and to formulate a plan based on their understanding of the patient's status?

Any cognitive strategy for reconciling medication lists depends on mental models (i.e., a mental representation of a cognitive task), knowledge, and expertise related to disease and medical therapy. Understanding the cognitive process of MR is an important early step to facilitate process improvements and ultimately safety. Tools and concepts found in cognitive research (Nemeth 2004; Woods 1993) may be used to study cognitive processes in MR. In other clinical problems, human factors analyses produced robust tools that can improve task performance (Lin et al. 1998). An extensive body of literature related to cognitive processes related to clinical diagnostic reasoning (Patel et al. 1997; 2002; Round 2001; Thomas et al. 2008; Vickrey et al. 2010). For example, a previous study (Kushniruk et al. 1998) has shown that expert physicians organized diagnostic knowledge on the basis of similarities between disease categories, forming 'small worlds' consisting of small subsets of diseases and their distinguishing features. Nevertheless, we could not find a cognitive exploration of disease management within a MR process.

Hence, the goal of this study is to understand the cognitive process of MR, demonstrate how cognition can be investigated in medicine, and describe some of the variability in individual MR strategies. We describe here an experimental view of MR created through simulation that reveals patterns in the MR cognitive process, including examples of mental modeling.

## 2 Methods

All participants were clinicians practicing in a department of anesthesiology and critical care, whose work involves MR. We obtained Institutional Review Board approval for this experiment and consent from the 24 clinician participants. We produced a simulation to probe the nature of cognition in MR using a "card game" or formally, card-sorting task. Simulation approximates a clinical scenario from which cognitive information can be extracted using visual artifacts or verbal protocols (such as a "think aloud" method or an interview). The card-sorting method (also called an affinity diagram) is a validated exploratory research method in the cognitive and social sciences (Coxon 1999). It is a reliable method for gathering user input. Its freeform nature allows flexibility of thinking with minimal constraint on the users' thoughts. Through card

**Table 1** Case description: diseases and treatments for a potential patient

Diseases	Treatments
Deep vein thrombosis (2001)	Fluticasone (Advair Diskus)
Coronary artery disease (2004)	Clopidogrel (Plavix)
Cerebrovascular accident (2005)	Potassium chloride
Two myocardial infarctions (both in 2004)	Alprazolam (Niravam)
Atrial fibrillation (2004)	Aspirin
Chronic obstructive pulmonary disease (unknown year)	Home oxygen Atorvastatin (Lipitor)
Hypertension (2004)	Paroxetine (Paxil)
Depression (1989)	Digoxin (Lanoxin)
Head/neck cancer (1989)	Albuterol

The patient is a 66-year-old female patient scheduled for a wide local excision of a tongue lesion

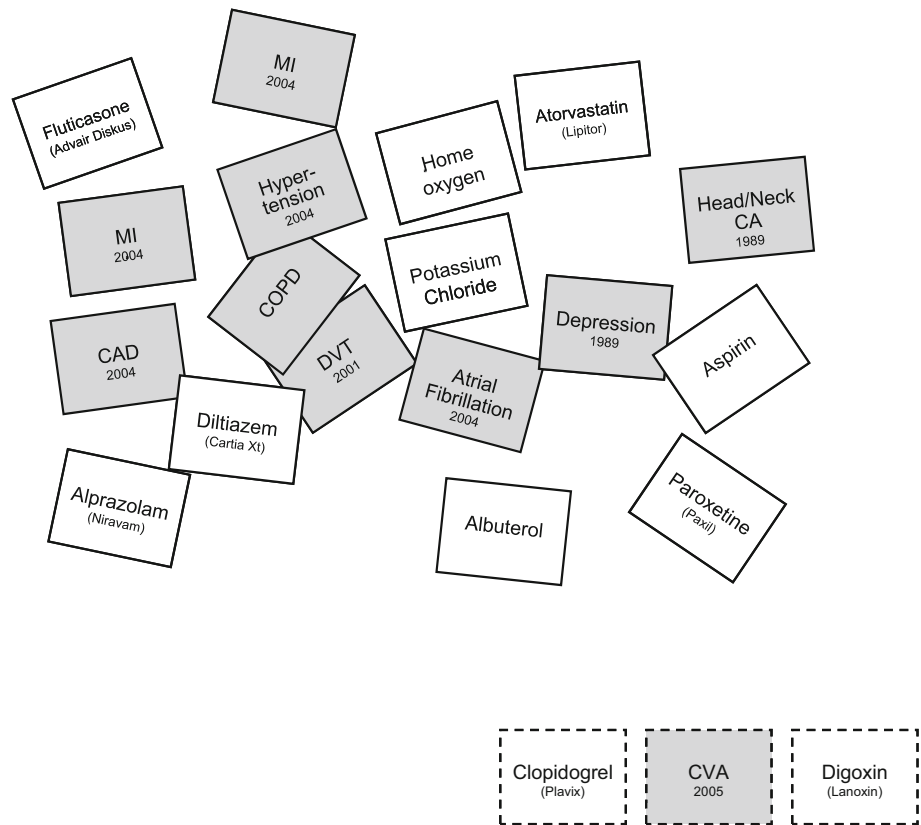
sorting, investigators can explore ways in which users cope with given tasks, information users need to complete tasks, and the strategies users rely on to cope with uncertainty or missing information. These explorations can yield useful mental models. Mental model analysis explores the way individuals construct the concepts behind a complex phenomenon in their minds to solve problems, anticipate changes, and make decisions. Mental modeling has been used to describe human-technology interaction (e.g., aircraft pilot performance; Sarter et al. 2007).

The simulation was based on patient data from the Anesthesia Preoperative Medicine Clinic at the University of Chicago Medical Center. Abstracted patient records were used to produce a fictional case for pre-operative assessment by an anesthesia provider. All participants were faced with the same clinical case described in Table 1. We chose this case to replicate a high level of medication complexity typical of that encountered in daily practice. Such case vignette methodology has been shown to be an effective and cost-efficient method for measuring physicians' clinical decision-making (Luck et al. 2006; Peabody et al. 2000; Veloski et al. 2005).

Patient medical diagnoses and medications were printed on individual cards that the participant could arrange on a table. To help participants differentiate between medications and diseases, disease cards had a gray background and medication cards had a white background. We placed the cards on a dark table for maximal contrast. All participants began with the exact same arrangement (Fig. 1). If a drug had a commercial name, it was printed in smaller letters below the generic name. If a disease's year of occurrence was available, it appeared on the card.

The disease cards fit several categories, yet several diseases could be clearly categorized as cardiovascular

**Fig. 1** Original card arrangement. Abbreviations: *CAD* coronary artery disease; *DVT* deep vein thrombosis; *COPD* chronic obstructive pulmonary disease; *CVA* cerebrovascular accident; *MI* myocardial infarction



disorders. Moreover, these diseases were linked. For example, hypertension is a risk factor for cardiovascular disease, which can lead to myocardial infarction. The links between the diseases and with the drugs used to treat them were critical features of the spatial exercise; we hoped that these links would be expressed in the card arrangements.

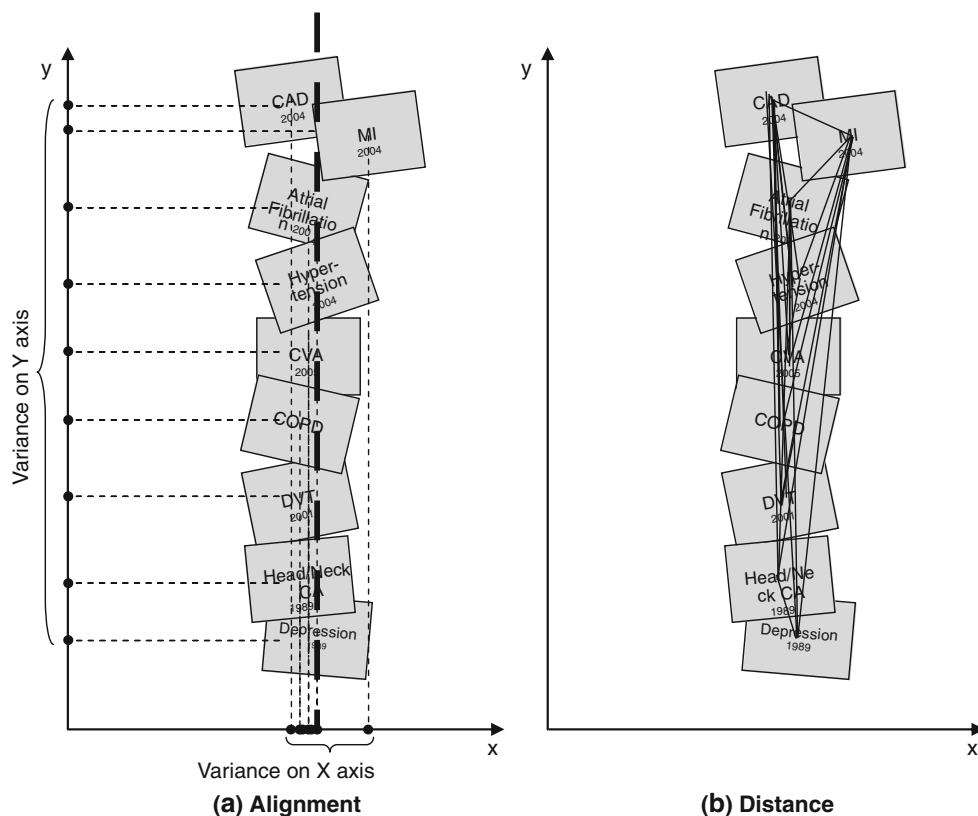
The experiment was performed in a quiet room. The participants sat in front of the table and were instructed to arrange the cards in a way that made sense to them in the clinical context of pending surgery and pre-anesthetic evaluation, while “thinking aloud” and sharing their thoughts during the card-sorting process and the rationale beyond their choices. The investigators in the room presented a standardized set of directions, answered queries, and asked questions at the end of the arrangement. We intentionally designed the task to be simple to understand with minimal instructions to elicit a natural response. The purpose was to have the participants articulate their intuitive coping with MR. We emphasized to the participants that there was no “good” or “bad” solution for the “game”, that it was not an evaluation of their clinical abilities, and that we were interested in understanding the process rather than the outcome. Three cards (cerebrovascular accident, clopidogrel, digoxin) were withheld at

the beginning of the experiment to assess participants’ response to potentially unavailable data. We exposed these cards to the participants during the experiment. The same cards were hidden for all participants. A video camera recorded hand movements and conversation, without capturing participants’ upper bodies to preserve confidentiality.

## 2.1 Data analysis

We analyzed the final spatial set for each participant. The basic premise beyond the analysis was that the spatial arrangement of the cards represented the subject’s cognitive mental model for reconciling the problem. Spatial cues such as card clustering, ordering, and relative positioning (e.g., near to far, side by side, etc.) would represent the way clinicians make sense of such information in real-life settings. We developed a method to quantify spatial positioning of cards and to explore card arrangement patterns. We translated the final table arrangement into a graphical image. The position of each card was recoded by its rectangular coordinates ( $x$ ,  $y$ ) in units of pixels. Because the table was rectangular, we adjusted the coordinates for 1:1 scale. The analysis was designed to answer two questions:

**Fig. 2 a** Estimation of card alignment. This figure describes an example of a vertical line, deduced from the small variance of the  $X$  coordinates relative to the variance of the  $Y$  coordinates. **b** Estimation of distances between cards. The **black bold lines** represent the distances between each cards pair



### 2.1.1 Do the cards fit a linear pattern?

The Levene's test for equality of variance was used to compare the variances on  $X$ - and  $Y$ -axis. A linear order would exist if the variance of either the  $X$  or  $Y$  coordinate was relatively smaller than the variance of the other coordinates (Fig. 2a). The binary statistical decision for each participant based on the Levene's test was whether the arrangement had a line-like shape. We then ran a non-parametric binomial test to test the hypothesis of a line-like arrangement across all the participants.

### 2.1.2 Are the cards sorted by a similar order?

We were interested in exploring patterns in arrangement and grouping. One way to identify patterns in arrangement is to look for cards that are usually positioned close to or far from each other. The Euclidean distance between each card pair was calculated ( $d_{ij} = \sqrt{(y_i - y_j)^2 + (x_i - x_j)^2}$ ).  $n$  cards will have  $n(n - 1)/2$  distances for each participant (Fig. 2b). To make adjustments according to similar proportions for all participants, an adjusted distance was calculated according to the longest distance in the entire set of each participant (to avoid variance among different

participants). We used the Friedman test for ranking to compare the adjusted distances.

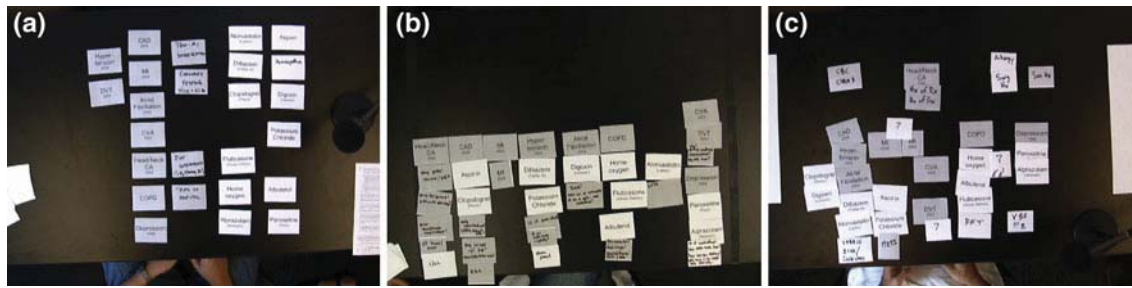
## 3 Results

### 3.1 Descriptive data

Twenty-four participants participated in the experiment. Of the 24, 6 (25%) of them were attending physicians (with a mean of  $17.2 \pm 4.4$  years of clinical experience, including residency); 5 (20.8%) were certified registered nurse anesthetists (with a mean of  $9.5 \pm 5.5$  years of clinical experience); 10 (41.7%) were residents (with a mean of  $3.3 \pm 1.1$  years of clinical experience); and 3 (12.5%) were third-year medical students. Ten (41.7%) of them were women and 14 (58.3%) were men.

### 3.2 Final sets analysis

Subjects organized the cards in different formats, including vertical, horizontal and freeform arrangements. Figure 3 shows examples of different formats. A glance at the diseases list arrangement revealed a reproducible pattern. The participants mostly arranged the disease cards in a line,



**Fig. 3** Example of final sets of the cards **a** vertical arrangement (subject 1), **b** horizontal arrangement (subject 5), **c** freeform arrangement (subject 4)

**Table 2** Levene's test for equality of variance of the  $X$  and  $Y$  coordinates

Participant	Levene's F	Significance	Pattern decision
1	15.21	0.001	Linear
2	36.47	0.000	Linear
3	17.79	0.001	Linear
4	0.62	0.442	Not linear
5	19.53	0.000	Linear
6	20.29	0.000	Linear
7	11.87	0.003	Linear
8	3.92	0.063	Not linear
9	15.34	0.001	Linear
10	9.56	0.006	Linear
11	0.42	0.527	Not linear
12	10.72	0.004	Linear
13	19.13	0.000	Linear
14	17.71	0.001	Linear
15	9.52	0.006	Linear
16	24.12	0.000	Linear
17	13.16	0.002	Linear
18	13.94	0.002	Linear
19	15.83	0.001	Linear
20	10.57	0.004	Linear
21	13.82	0.002	Linear
22	20.77	0.000	Linear
23	0.00	0.974	Not linear
24	2.41	0.138	Not linear

Statistical significance of the Levene's F implies a line-like pattern of the cards (Fig. 2a)

with a constant order. With some exceptions, the line spread from cardiac conditions (CAD, MI, CVA) on one extreme to depression on the other extreme.

### 3.2.1 Do the cards fit a linear pattern?

The hypothesis of equal variances was rejected in 19 of the 24 participants (79%) (Table 2). This result means that in 79% of the participants, the variance of the coordinates'

projections on one axis was significantly different from the variance on the other axis, arguing for a line-like pattern of the cards (Fig. 2a). The non-parametric binomial test revealed a one-tailed exact significance level of  $p < 0.001$ , i.e., 79% of the 24 participants is a significantly large proportion to reject the null hypothesis of an absence of a line-like arrangement. In other words, a linear pattern was revealed.

### 3.2.2 Are the cards sorted in a similar order?

Once we revealed that the cards were arranged in the form of a line, we were interested in exploring patterns in the arrangement along the line. The Friedman test rankings (Table 3) showed that the most distant diseases were the cardiac diseases (myocardial infarction (MI), atrial fibrillation, hypertension, and coronary artery disease (CAD)) and depression. The diseases found most commonly together were the same cardiac diseases. The differences between the ranking of the 45 distances between all possible pairs of diseases (formed by 10 cards) were statistically significant (Friedman's  $\chi^2(44) = 291.9$ ,  $p < 0.001$ ). These results suggest that the subjects arranged the disease cards in a similar order, from cardiac diseases to depression.

Data from the verbal protocols and the post-experiment interview enrich the picture on strategies emerged from the quantitative analysis. These data strongly suggest that the subjects used the medical conditions as an anchor of their arrangement; they arranged the conditions by organ system and their relevance to the anesthetic plan, in a similar order, from cardiac diseases to depression. Examples are provided in Fig. 4.

## 4 Discussion

In this simulation study, we found that anesthetists at different levels of training demonstrate a common tendency. They consistently organize medical conditions linearly

**Table 3** Friedman's test for ranking of the adjusted distances between cards

Order	Pair	Mean rank
1	MI <sub>1</sub> –MI <sub>2</sub>	5.68
2	Atrial fibrillation–hypertension	6.68
3	CAD–MI <sub>2</sub>	10.05
4	CAD–MI <sub>1</sub>	10.98
5	MI <sub>1</sub> –hypertension	12.70
6	MI <sub>2</sub> –Hypertension	14.84
7	CAD–hypertension	15.23
8	MI <sub>1</sub> –atrial fibrillation	16.30
9	CAD–atrial fibrillation	16.68
10	MI <sub>2</sub> –atrial fibrillation	17.57
11	DVT–COPD	17.86
12	CVA–hypertension	18.64
13	DVT–depression	19.32
14	CVA–MI <sub>2</sub>	19.45
15	CVA–atrial fibrillation	19.93
16	COPD–depression	20.86
17	CVA–MI <sub>1</sub>	20.98
18	DVT–head/neck cancer	21.30
19	COPD–head/neck cancer	21.50
20	CAD–CVA	22.02
21	Atrial fibrillation–COPD	22.98
22	COPD–hypertension	23.09
23	Depression–head/neck cancer	23.41
24	DVT–atrial fibrillation	24.68
25	DVT–CVA	25.68
26	DVT–hypertension	26.05
27	MI <sub>1</sub> –COPD	26.30
28	DVT–MI <sub>2</sub>	26.39
29	DVT–CAD	26.73
30	CVA–COPD	26.77
31	Hypertension–head/neck cancer	26.95
32	MI <sub>2</sub> –COPD	27.25
33	CAD–head/neck cancer	27.27
34	DVT–MI <sub>1</sub>	27.84
35	CAD–COPD	27.98
36	Atrial fibrillation–head/neck cancer	28.50
37	MI <sub>2</sub> –head/neck cancer	29.80
38	MI <sub>1</sub> –head/neck cancer	29.95
39	Hypertension–depression	30.86
40	CVA–head/neck cancer	31.05
41	Atrial fibrillation–depression	31.95
42	CVA–depression	32.00
43	MI <sub>1</sub> –depression	33.93
44	MI <sub>2</sub> –depression	34.43
45	CAD–depression	34.59

*Notes* The mean ranks are the average of the ranks of each couple across all participants. The smaller mean rank indicates that across all participants, the cards were closer. Each participant had 45 pairs (the distances between all two card combinations). *CAD* coronary artery disease; *DVT* deep vein thrombosis; *COPD* chronic obstructive pulmonary disease; *CVA* cerebrovascular accident; *MI* myocardial infarction

along a common axis, frequently beginning with cardiovascular system diseases and ending with an oncologic or a psychiatric disease. This arrangement was true for attending physicians, residents, nurses, and medical students. The pattern suggests that arrangement along organ systems is common and useful when sorting a complex medical history. All participants were clinicians practicing in a department of anesthesiology and critical care (except for the students, who were on a clerkship rotation in the department). Similarities in training might explain some of this pattern; however, the fact that this arrangement pattern repeated across different clinicians emphasizes its persistence. Furthermore, although the arrangement strategies were different (Fig. 3), the linear pattern persisted.

The diseases that are most commonly together were myocardial infarction (MI), atrial fibrillation, hypertension, and coronary artery disease (CAD). All of these diagnoses involve the cardiovascular system and recapitulate current concepts of cardiovascular disease. The most distant card relationships involved the diagnosis of depression and its association with CAD, both myocardial infarctions, cerebrovascular accident (CVA), and atrial fibrillation. Although depression is associated with cardiac disease, the pathophysiology is less clear. Moreover, depression is considered a psychiatric diagnosis. Medications for cardiovascular disease (and, by extension, cerebrovascular disease, which shares a common concept of disease progression) are likely considered separately from those that treat depression. Inline with the “small worlds” hypothesis (Kushniruk et al. 1998) (i.e., physicians organize diagnostic knowledge on the basis of similarities between disease categories), the clinicians apparently grouped together diseases sharing overlapping features, on the basis of the presence of key medical findings.

We found support for the quantitative findings in a qualitative analysis of data from the verbal protocols and the post-experiment interview. These data enrich our understanding of the strategies uncovered in the quantitative analysis, by providing a rationale beyond the similar order. These data strongly suggest that the subjects used the medical conditions as an anchor of their arrangement and arranged the conditions by organ system and their relevance to the anesthetic plan.

Our methods have several strengths. Using an abstracted anesthetic case for the simulation improves its fidelity and helps test real-life medical complexities. Withholding some cards simulated the problem of missing information, a common source of challenge in MR. The “card game” itself shed light on participant cognition by creating a visual artifact that participants could manipulate into patterns. Our measurements quantify a qualitative observation and demonstrate its statistical significance.

**Fig. 4** Example citations from the verbal protocols supporting the arrangement of the conditions along a line, by organ system, from cardiac diseases to depression

"...So I'm going to then to group them, problems together probably by system... cardiovascular, pulmonary and then we have cancer in there and depression...and then I would potentially further organize these into what I would consider more severe or important based on my plan...in the sense where I tried to group them by a system. I put these [the cardiac conditions] up here because they're, from my point of view more important for me..." (Subject 1).

"...When I originally started organizing it I thought about just putting all the medical problems on one side in somewhat of a rank... and just kind of organized it, these things [the cardiac conditions] to me are more related, actually all these things involving the heart are kind of related ...this is in the same kind of row and these are all involving the heart and the heart functions, so that I kind of arranged that first so and just moving systematically, neurological system, vascular system as well, somewhat related to the heart, and lungs..." (Subject 2).

Although interesting, our findings are only an early step in understanding what the cognition of MR encompasses. Sorting cards is different from actual patient care; thus, our methods may miss some of the nuances that make reconciliation more difficult a clinical setting. The reasons for the persistence of a linear, organ-based, and commonly sorted order for medical conditions are unclear. We speculate that this persistence represents a common, robust strategy, but it may also be a custom that persists for reasons other than facilitating cognition.

The implications of these findings for the safety of MR suggest a path to improvement. By studying how clinicians make sense of disease lists, the elements of an effective MR can be understood and tools and methods to improve safety can be suggested. It is also an opportunity to develop tools to help strengthen robust and successful characteristics of clinicians' cognition, while bridging potential failures and gaps in knowledge.

Our methods are a first explorative step to reveal a practitioner's cognition in MR. This step helps define the strengths and faults in the MR process. It is also an opportunity to develop tools to help strengthen robust and successful characteristics of clinicians' cognition, while bridging potential failures and gaps in knowledge. Future research shall probe into the ways clinicians sort and think about reconciliation problems and should consider an increased sample size and a controlled sample group to allow comparisons between subgroups.

## 5 Conclusions

In a simulation to probe the nature of cognition in MR, we found that anesthetists at different levels of expertise demonstrated a common tendency. Most of the participants arranged diseases along a straight line. With only few exceptions, the diseases were arranged along the line in a fixed order, from cardiac conditions (CAD, MI, CVA) to depression. These results demonstrate that, although clinicians employ a variety of coping strategies while reconciling patients' medical and medication histories, there are common reconciliation strategies. Understanding such strategies, as well as the mental models clinicians hold for the reconciliation process, may help investigators understand the process itself. Implementation of organizational processes that conform to the clinicians' mental model for MR is likely to facilitate safe practice.

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