Mental Models for Usable Privacy: A Position Paper

Kovila P.L. Coopamootoo and Thomas Groß

School of Computing Science, Newcastle University, United Kingdom
{kovila.coopamootoo,thomas.gross}@newcastle.ac.uk

Abstract. In this position paper, we propose a new approach to privacy decision-making that relies on conceptual representations of mental models. We suggest that helping users to construct mental models of privacy will facilitate privacy decisions and hence contribute towards usable privacy. We advance that usable privacy research will benefit from qualitative and quantitative user studies that first elicit users' mental models of privacy and second aim to build a composite model of the concept maps of users' mental models. The links between the concept maps and deductive and inductive reasoning, and System 1 and 2 of the dual-process theory, are thought to potentially provide valuable insights for future usable privacy research. We also propose that the composite model might provide routes to privacy decisions and enable us to develop strategies akin to nudges aimed towards facilitating privacy behaviour.

Keywords: Usable privacy, mental models, dual-process, System 1, System 2, deductive, inductive, privacy decision-making.

1 Introduction

A privacy dichotomy is often observed online that is although users have privacy concerns, observed online behaviour often does not match their claimed concerns [1,2]. An explanation for the dichotomy could be that the increasing use of the Internet and accompanying technologies in society is blurring the distinction between the public and private online leading to fuzziness when evaluating privacy. This in turn contributes to the difficulty in making privacy decisions, an issue that is not corroborated with the offline world.

Online privacy designs vary with contexts and include two main approaches. First the privacy-by-policy approach that provides notice and choice, such as via the privacy policy in E-Commerce and second, the privacy-by-architecture approach that targets privacy protection at the design phase through minimisation of data collection, anonymity and unlinkability of individuals [3]. This approach is also referred to as privacy-by-design [4,5]. The privacy-by-policy approach is often found to be too legalistic, confusing, un-usable and, at best, a substitute for more meaningful privacy protection [6]. It relies on the self-regulation approach [7] that views privacy as a commodity that can be traded in the market place. The self-regulation approach assumes rational behaviour from users who are expected to conduct a risk assessment.

T. Tryfonas and I. Askoxylakis (Eds.): HAS 2014, LNCS 8533, pp. 410–421, 2014.

The evaluation of one's privacy and associated risks and benefits requires high cognitive effort and rational decisions that conflict with research on psychological biases and attributions that underpin the behaviour of individuals [8]. The privacy-by-design approach aims to enable users to protect their privacy by providing appropriate tools including access control, encryption and anonymous credentials mechanisms. While these abstract the technical complexity such as through eIDs, users still need to have transparent choices and be able to engage in an intuitive way.

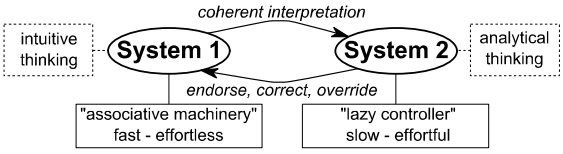

Fig. 1. The Dual-Process Model

Therefore, whilst privacy evaluation is embedded within social behavior offline [9] and can be thought to be part of effortless interactions, in the online environment users are expected to make complex decisions. These decisions may be governed by different cognitive processes, for which we introduce the dual-process model as abstraction, that distinguishes between effortless intuitive and effortful analytical cognition. Hence, investigation into the type of thinking users engage in can provide valuable insights for usable privacy research. Moreover the human-computer interaction (HCI) community believes that users build and use mental models to guide the way they learn and interact with computers [10]. Research has previously tapped into conceptual representations of mental models to help users better understand and predict system behaviour [10,11,12].

In the following sections we first provide an exposé that highlights the differences in modes of offline versus online privacy with the help of the dual-process model. This is followed with a review of mental models literature, of the use of mental models in HCI and existing privacy and security research's links with mental models. We then establish our research questions and elaborate on approaches to elicit, analyse and represent mental models of privacy while proposing links with deductive-inductive studies and findings. We suggest investigations of the effects of privacy mental models on users' dual-process thinking methods. We discuss how our approach aligns with established mental models research together with the usefulness of mental models for usable privacy research before concluding the paper.

2 Background

In this section we first discuss the links between online and offline privacy with dual-processing modes of thinking and decision-making. Second we review mental models literature, and in particular its use within HCI. This section ends with a brief of previous mental models research related to privacy and security.

The Dual-Process Model. In our approach to systematically analyse privacy decisions we use the so called *dual-process model* as a basis (see Figure 1), which is used within cognitive psychology literature to explain that people have the ability to employ dual-process thinking and reasoning [13,14,15,16]. The model states that there exist two systems in human cognition, called System 1 and System 2. System 1 is effortless and includes intuitive operations; System 2 is effortful and includes analytical operations. System 1 facilitates many automated processes of cognition including processing of visual input and cues and aims to create a coherent representation and interpretation of the world. System 2 is often described as 'lazy' as it only intervenes at times, by endorsing, correcting or rejecting decisions.

Privacy in Relation to the Dual-Process Model. Privacy is a concept with behavioural dimension in that individuals dynamically manage their privacy according to different situations in social life. Whilst users are able to manage their privacy effortlessly offline, in the online environment they are expected to make complex decisions [7]. Privacy enables a dialectical state [9] that allows individuals to be both connected and autonomous. The interplay of needing both privacy and openness influences the decisions individuals make about the way they manage their information. As a consequence, they do not usually require complete privacy. Rather, they are happy to share information with others as long as certain social norms are met, that is contextual integrity of the shared information is maintained [17]. Therefore individuals' privacy requirements vary according to contexts and over time and are very much linked to how people present their identity. Privacy elaboration offline is implicit within behaviour [18,9] and by conjecture happens intuitively and effortlessly, linking offline privacy decision-making to System 1 method of thinking which is quick and automatic [13,14,15,16]. System 1 uses associative memory to help construct a coherent interpretation when making sense of the world in an instantaneous and effortless fashion. During associative activation, evoked ideas trigger other ideas in a spreading cascade of mental activity that is bounded together by coherence. Each element of the association connects, supports and strengthens each other and can in turn quickly generate emotions and expressions or behaviour [16].

However in the online environment the focus of interactions is often explicitly on the primary task making privacy the secondary goal. To make a correct privacy evaluation online that adheres to offline privacy decision-making, users need to fully assimilate what personal information is shared to whom in which manner, who will own the information, what does disclosing personal information in a particular context means that is how it affects their self-presentation [19], how it relates to or modifies their identity [20], whether there is a risk of conflict between roles played by identities and how to resolve these conflicts. Current designs expect users to understand what privacy mechanisms are available at their disposal and how to use these to their benefit. Therefore online privacy designs also expect users to elaborate about their privacy by allocating attention to the effortful mental activities that demand to consciously reason and construct thoughts in an orderly series of steps that is via System 2. System 2 helps to follow rules, compare objects on several attributes and to make deliberate and systematic choices [16].

Individuals make countless decisions involving various thought processes every day. These decisions can range from ones that are barely noticed and soon forgotten to others that are highly consequential. The classical view of decision-making in literature refers to 'rational theory of choice' that postulates that individuals have orderly preferences that obey certain rules [21]. Therefore when faced with making a choice, decision makers are assumed to gauge subjective utility and to choose the alternative with the highest utility. In the event of uncertainty about the outcomes, decision makers are believed to calculate an option's expected utility. However this standard view is an inadequate model of how decisions are actually made. Models that account for a variety of human resource constraints such as bounded attention and memory capacity and limited time have instead been proposed including prospect theory [22] and status quo or regret theory [23]. Moreover, individuals' preferences are heavily shaped by particular perceptions of risk and value, by influences on attribute weights, by the tendency to avoid conflicts, by salient factors and emotions leading to the literature on judgment and decision-making and heuristics and biases [16]. As shown in Figure 1, System 1 quickly proposes intuitive judgments to problems as they arise and System 2 monitors the quality of these proposals that it may endorse, correct or override [24]. Since the capacity for mental effort is limited [25], effortful processes tend to disrupt each other whilst effortless processes neither cause nor suffer much interference and the effect of concurrent cognitive tasks can provide a useful indication of whether a mental process belongs to System 1 or 2.

Mental Models. Mental models are 'small-scale models' of reality constructed by the mind to help anticipate events, to reason and underlie explanations [26]. They are therefore internalised, mental representations of a device or idea that facilitates reasoning [27]. Johnson-Laird developed the mental models theory that explains deductive and inductive reasoning [27,28]. Although the theory has suffered criticisms [29], it is still considered an important part of mental models research and has been linked to dual-process approaches through conditional reasoning [30]. This sub-section reviews these aspects of mental models and introduces means that help users form mental models, and methods of eliciting, analysing and representing mental models that are further explored in later sections.

The mental model theory makes several assumptions aimed at relieving the load models place on working memory [31]. During reasoning, individuals can understand the meaning of assertions, envisage corresponding situations and ascertain whether a conclusion holds in them. Mental models theory however postulates that reasoning is not based on syntactic derivations of logical forms but rather on manipulations of mental representations of situations [32,33] that yield both deductive and inductive inferences [34].

Deductive reasoning involves making inferences on the basis of some given premises: a conclusion must be true given that the premises are true. Mental model theory postulates that deduction is a semantic process akin to the search for counterexamples that does not increase semantic information. Deductive mental models include logical and causal mental models [35]. Causal models differ from logical ones by drawing on information in long-term memory structures as opposed to

logical models that are created on the spot and only involve information active in working memory [35].

Compared to deduction, induction is a process that increases semantic information. Given a set of premises, inductive conclusions might go beyond what is given in the premises to eliminate possibilities. Johnson-Laird postulates that since induction depends on knowledge, it is constrained by availability and representativeness heuristic [36]. Moreover, some inductions are implicit in that they are rapid, involuntary and unconscious whereas others are explicit having slow, voluntary and conscious properties. Mental models theory has suffered criticisms such as for example Evans et al. [29] argue that the mental models theory for conditional reasoning [37] is flawed for not accounting for suppositional theory. Gauffroy and Barouillet [30] propose to resolve the theoretical conflict by differentiating between two kinds of reasoning and links to a dual-process theory that integrates heuristic-analytical modes within conditional mental model theory [38].

A variety of methods exist for forming, eliciting, analysing and displaying users' mental models as reviewed by Sasse [39]. Analogies that are types of similarities in which analogous situations share common patterns of relationships [40] and metaphors that use the same principle but involve semantically distant domains [10] can be used to help users form mental models. Although users' mental models can be elicited via interviews or think aloud methods, the concepts and relations between the concepts present within users' mental models need to be identified and extracted to depict users' mental models. Concept mapping is one such approach that can show concepts as vertices and relationships as edges within a graph that can be directed, weighted or labelled or a combination of these [41]. Exploration of the concept map could give an indication of the thought processes or reasoning approaches users are engaged in. A more detailed discussion of these methods is provided in the following sections.

Mental Models in HCI. In HCI, models are used for various purposes and Norman [10] offers some distinctions between the different models of a system including the target system, the conceptual model of the target system, the system image, users' mental models and scientists' or researchers' conceptualisation of a mental model. The system image can be thought to have the most direct and immediate influence on the user since it is through the systems' image, its appearance and behaviour that the user interacts with the system.

It is thought that users build and use models to guide the way they learn and interact with computers. Mental models enable them to predict and explain the operation of a target system through internal representations of themselves and the objects they interact with [10]. Evidence suggests that giving users a conceptual model of a system before using a system or rather than procedural instruction enhances user learning with the model suggested to serve as a knowledge organiser that prevents confusion and promotes understanding of the system [11,12]. Users given models also perform better in complex tasks compared to those not provided with a model [11] and are expected to be more apt at troubleshooting and problem solving [42].

Mental Models in Privacy and Security. Analogies and metaphors function as tools of thought that help structure unfamiliar domains [40] and are useful when forming mental models. Metaphors have been proposed in privacy research, for instance Lederer et al. [43] proposed a 'situational faces' metaphor that aims to provide guidance for supporting notice and consent. Richter-Lipford et al. [44] proposed the 'audience-view' metaphor to help users form a model of the recipients of their information disclosure in Facebook. The Primelife project explored approaches to help users form mental models of the data minimisation property of the concept of anonymous credentials [45]. Although the research found that an adapted card-based approach metaphor evoked better mental models of anonymous credentials there was also a suggestion for the need for a better design paradigm to improve user understanding [46].

Moreover, metaphors are often used within information security to communicate risk to users. Camp [47] reviews metaphors currently in use within security including the physical security model through control of perimeters, the medical model that refers to worms and viruses, the criminal model with reference to malicious codes and breach, the warfare model with the idea of firewalls and DMZs and vulnerabilities leading to downtimes and failures such as through denial of service akin to a market model. They also recommend the need for further mental models research in the area of privacy and security.

3 Research Questions

In light of the previous sections we propose research in the area of mental models for online privacy. We believe such approach will contribute to the research space covering effectiveness and usability of online privacy.

Since mental models are small-scale representations of reality consisting of relations and semantic information about objects, we believe it will help to address the gap in usable privacy research by assisting to channel user perceptions, to form judgment and to guide decision-making. The conceptual representations of mental models will help users better understand how the system works and enhance their ability to predict system behaviour and in doing so help them towards making intuitive judgments. We first assume that System 1 and System 2 of Figure 1 can be active concurrently during privacy decision-making. The contribution of the two systems in determining judgments can depend on task features (such as the type of privacy design including the system image characteristics), characteristics of tasks privacy evaluation is secondary to (such as online shopping, social networking or micro-blogging) and individual characteristics such as time available for deliberation, mood, cognitive impulsiveness, intelligence. As System 2 monitors the proposals made by System 1, it can endorse it or expend mental effort to evaluate the context such as by comparing models, analysing and discarding unmatched models, and restructuring and ameliorating existing models. Moreover as evidenced with chess masters who perform more intuitively with experience [48], by conjecture we propose that users will be able to more intuitively identify privacy design models with

experience. Thus our main research question is: 'how do mental models of privacy affect privacy decision-making?' The question includes mental models derived via inductive or deductive reasoning and judgments involving System 1 or 2. Our research problem therefore involves the need to: establish the contents of mental models, the concepts comprised in users' models and their relationship for different privacy design approaches and contexts; analyse the models with respect to strength and weights of connections, the type of reasoning involved, effort required, and compare with expert models; develop a composite conceptual representation of mental models that can potentially show different links to decisions; make use of the composite model to infuse designs with triggers and interventions aimed at enhancing usable privacy; and investigate the effect of particular interventions on performance (such as the number of errors in understanding privacy operations, users' feeling of certainty, type of privacy related behaviour), user effort required and reasoning approach used.

4 Mental Models of Privacy

In this section we first look at methods for eliciting mental models of privacy followed with analysis methods and approaches to represent conceptualisations of users' mental models. We also propose study designs aimed at assessing the impact of the conceptual representation of privacy mental models or of links within the conceptual representation that can act as triggers.

User Mental Models of Online Privacy. As privacy designs are often claimed to be un-usable, determining the contents and structure of users' mental models of different privacy designs could lead to in-depth understanding of privacy HCI. This could hint to ways of tuning the system image to users' expectations and potentially enhance their predictive power. Users' mental models have been gathered before via a variety of methods including interviews [41], problem-solving tasks, teach back procedure [49] or having users draw their mental models [50]. The quality in terms of complexity and structure of the model elicited can be thought to be primed by data collection design including the type of questions set to study participants (such as open versus closed-ended questions), the content of the questions (such as whether privacy is explicitly mentioned), the task associated with the information gathering process and potentially other heuristics. Therefore data collection methods for privacy mental models might benefit from a mix of approaches that generate rich indicative data that informs research on better suited approaches to design specific user studies. For instance interviews might be linked with structural knowledge elicitation [51] or network task analysis [52], procedural knowledge analysis and think aloud protocol analysis for problem solving for troubleshooting and teach back data [49].

However, we posit to start with open questionnaires or think aloud data that can be analysed via grounded theory coding techniques including open and axial coding [53]. This approach has been used before to first identify concepts, define relationships between concepts, display the resultant coded mental representation graphically within mental models research [41]. The depiction of relations between concepts and

their semantic relationship can adhere to a concept mapping approach [41]. Concept mapping is common to investigation of students' mental models [54,55,56]. As a portrayal of the users' mental model, the concept map can contain propositional and visual type information such as strings and symbols corresponding to natural language, analogies of the world and images that are perceptual correlates from a particular point of view. The concept map can be measured quantitatively based on a scoring protocol [57] with edges weighted or analysed qualitatively. For instance labelled edges and vertices can potentially lead to understanding of the strength of concepts in influencing others and also in the type of reasoning involved. Performance and effort data can also be collected to later relate the model generated with dual-process theory.

Composite Conceptual Model. A compilation and analysis of the concept maps obtained above can lead to a composite model. This composite conceptual model might in turn provide indications on the strength of particular concepts, their occurrence in different context, their relationship to other concepts and the paths to specific privacy decisions. The composite model can be compared to experts' model of privacy design and further lead to proposal for privacy designs that better match users' mental models. The composite model might also lead us to a series of inferences that suggest triggers or interventions that make use of System 1's intuitive and effortless approach.

User Studies. The impact of these particular interventions can then be investigated with user experiments. The experimental observations might not only provide data on improving usability of privacy designs but also on fine-tuning the composite model.

This part of our research will aim to identify the influence of specific interventions from the composite model on users' dual-process model mode of thinking as depicted in Figure 1 such as whether privacy within an E-Commerce context as opposed to a social network environment engenders effortless and intuitive methods of thinking of privacy or lead to effortful and analytical interactions. System 2 thinking competes for mental effort that users have of limited capacity. Therefore in conducting an experiment we would for instance design a condition that cognitively depletes users (such as via attempts to hold a long number in memory, ADD-3 to a 4 digit number or via participation in Wason's selection task [58]) and observe the effort required (or ease) to correctly conduct a privacy related task (in terms of time, number of errors made, certainty in actions, pupil dilation, correctness of think aloud account). If the privacy task also requires high effort, users might be prone to errors or not able to correctly assess their privacy. The impact of our interventions could then also be compared with existing methods of notifying or warning users.

5 Discussion

We pursue the discussion of our research approach for mental models for usable privacy in three strands. We first discuss the state of mental model research and methods as a basis for this research. Second, we review the paper's approach and, third, the possible outcomes for usable privacy.

We perceive that there is no unified theory of mental models and associated methodologies in sight. There are multiple approaches to elicit, analyse and represent mental models with the goal of establishing a conceptual model. Specific methodologies for user studies can give rise to dedicated analysis methods and representations of the conceptual model. For instance, on one hand think-aloud or verbal methods to elicit user input are particularly suited for concept maps, which can in turn be represented as undirected weighted graph with vertices modelling concepts and edges the relationships between them. On the other hand, inductive and deductive models can be elicited with premise-consequence completion tasks and likely modelled in a logic representation. Observing this panoply of approaches, we also need to account for their strengths as well as the criticisms they received for their shortcomings.

At this point, it is uncertain which particular methodology will benefit usable privacy decision-making the most. As established in Section 4, we perceive that the user's concept map, insights into deductive and inductive reasoning and the involvement of the dual-process systems may all be meaningful for privacy decision-making. The concept map seems promising as the associations encoded therein can give rise to priming and triggers activating adjacent concepts. The dual-process model and deductive-inductive reasoning link has been made in the critique of mental models by Evans et al. [29] and propositions by Gauffroy and Barouillet [30]. Given that recent research in the privacy space has linked bounded rationality concepts with privacy decision-making, such as the research pursued by Acquisti and Grossklags [2], it is a natural step to investigate the involvement of System 1 and System 2 in privacy decision-making. Hence, we are considering multiple methodologies to establish a conceptual model for privacy decision-making, each coming with its own user study, analysis and representation methods. The final conceptual model is likely to be a composite of the outcomes of each approach. We find it conceivable that an abstracted representation may encode all outcomes in one model, for instance, in a directed, weighted, labelled graph, in which edges do not only encode associations, but also deduction and induction between concept vertices.

Finally, we need to consider how this research would support usable privacy. We observe that privacy design has mainly been influenced by expert models and we see a necessity to complement those with insights in user mental models. We follow the rationale that interventions such as stimuli, triggers or nudges should speak the user's language and we consequently attempt to gain insights in that with a multi-pronged approach of concept maps, deductive and inductive strategies and dual-process activation. We aim to make the resulting conceptual model a tool to plan interventions. Consider the hypothetical example that the concept 'best friends' and the concept 'consideration in disclosure' (or 'don't talk behind my back') are closely linked in the concept map. Then, priming with the 'best friends' concept can nudge towards privacy-friendly disclosure decisions. Therefore, the conceptual model can act as guidance to choose interventions from a larger portfolio, such as the nudge inventory of MINDSPACE [59]. Similarly, typical deductions observed in the user study can make the premise a suitable trigger. If we see evidence that privacy decision-making is largely governed by the automated and effortless System 1, as

suggested in the theory on the formation of mental models as proposed by Gauffroy and Barouillet [30], then an artificial invocation of System 2 is likely to change users' approach.

6 Conclusion

In this position paper, we make a case that research into user mental models is beneficial for usable privacy. Observing that mental model research has seen a diverse set of approaches and various criticisms, we focus on three areas that we deem most promising for the privacy domain: concept maps, deductive and inductive reasoning, and the activation of System 1 and System 2 according to the dual-process model. There exists a body of literature in mental model methodology as well as related areas such as behavioural economics that give us foundations in theory and modelling user studies. The research aims to establish a composite conceptual model, which will in turn inform design for usable privacy. In particular, the conceptual model will allow educated choices on the placement of interventions to support the privacy decision-making of the user.

Acknowledgement. This research on usable privacy is currently supported by the EU FP7 FutureID project http://futureid.eu) under GA n^{o} 318424.

References

1. Spiekermann, S., Grossklags, J., Berendt, B.: E-privacy in 2nd Generation E-Commerce: Privacy preferences vs. actual behavior. In: Proc. ACM Conf. E-Commerce, pp. 38–47 (2001)
2. Acquisti, A., Grossklags, J.: Privacy and rationality in individual decision making. IEEE S & P 3(1), 26–33 (2005)
3. Spiekermann, S., Cranor, L.: Engineering privacy. IEEE Trans. on S/W Eng. 38(1), 67–82 (2009)
4. Langheinrich, M.: Privacy by Design - Principles of Privacy-Aware Ubiquitous Systems. In: Abowd, G.D., Brumitt, B., Shafer, S. (eds.) UbiComp 2001. LNCS, vol. 2201, pp. 273–291. Springer, Heidelberg (2001)
5. Cavoukian, A.: Privacy by Design... Take the Challenge. Information (2009)
6. Milne, G.R., Culnan, M.J.: Strategies for reducing privacy risks: why consumers read (or don't read) online privacy notices? Journ. of Interactive Marketing 18(3), 15–29 (2004); and Privacy Commissioner of Ontario, Canada (2009)
7. Zwick, D., Dholakia, N.: Models of privacy in the digital age: implications for marketing and e-commerce. Research Inst. for Telecom. and Information Marketing (1999)
8. Tversky, A., Kahneman, D.: Judgement under uncertainty: heuristics and biases. Science 185(4157), 1124–1131 (1974)
9. Palen, L., Dourish, P.: 'Unpacking' privacy for a networked world. In: Proceedings of the CHI Conference on Human Factors in Computing Systems, pp. 126–136. ACM, NY (2003)
10. Norman, D.A.: Some observations on mental models. In: Human-computer Interaction, pp. 241–244. Morgan Kaufmann Publishers Inc., CA (1983, 1987)

11. Borgman, C.L.: The user's mental model of an information retrieval system: effects on performance. Dissertation abstract internations, 45, 4a (1984)
12. Halasz, F.G.: Mental models and problem solving in using a calculator. Doctoral dissertation, Standord University, CA, USA (1984)
13. Stanovich, K.E.: Who is Rational? Studies of Individual Differences in Reasoning, Elrbaum (1999)
14. Stanovich, K.E., West, R.F.: Individual differences in reasoning: Implications for the rationality debate. Behav. Brain Sci. 23, 645–726 (2000)
15. Evans, J.B.T.: Dual-processing accounts of reasoning, judgment and social cognition. Annual Review of Psychology 59, 255–278 (2008)
16. Kahneman, D.: Thinking fast and slow. Farrar, Strauss (2011)
17. Nissenbaum, H.F.: Privacy as contextual integrity. Washington Law Review 79(1), 119–158 (2004)
18. Altman, I.: The Environment and Social Behaviour: Privacy, Personal Space, Territory and Crowding. Brooks/Cole Publishing, Monterey (1975)
19. Coles-Kemp, L., Kani-Zabihi, E.: On-line privacy and consent: a dialogue, not a monologue. In: NSPW 2010 (2010)
20. Bennett, L.: Reflections on privacy, identity and consent in on-line services. Information Security Technical Report 14, 119–123 (2009)
21. LeBoeuf, R.A., Shafir, E.: Decision Making. In: Holyoak, K.J., Morrisson, R.G. (eds.) The Cambridge Handbook of Thinking and Reasoning (2005)
22. Kahneman, D., Tversky, A.: Prospect theory: an analysis of decision under risk. Econometrica 47(2), 262–292 (1979)
23. Kahneman, D., Jack, L.K., Thaler, R.: Anomalies: The endowment effect, loss aversion and the status quo bias. Journal of Economic Perspectives 5(1), 193–206 (1991)
24. Kahneman, D., Frederick, S.: A model of Heuristic Judgment. In: Holyoak, K.J., Morrisson, R.G. (eds.) The Cambridge Handbook of Thinking and Reasoning (2005)
25. Baumeister, R.F., Vohs, K.D., Tice, D.M.: The strength model of self-control. Current Directions in Psychological Science (2007)
26. Craik, K.: The nature of explanation. Cambridge University Press, Cambridge (1943)
27. Johnson-Laird, P.N.: Mental Models: Towards a Cognitive Science of Language, Inference, and Consciousness. Cambridge University Press, Cambridge (1983)
28. Johnson-Laird, P.N.: How we reason. Oxford University Press (2006)
29. Evans, J.B.T., Over, D.E., Handley, S.J.: Suppositions, extensionality, and conditionals: a critique of the mental model theory of Johnson-Laird and Byrne. Psychological Review 112(4), 1040–1052 (2002)
30. Gauffroy, C., Barouillet, P.: Heuristic and analytic processes in mental models for conditionals: an integrative development theory. Develop. Review 29(4), 249–282 (2009)
31. Johnson-Laird, P.N.: Mental models and human reasoning. Proceedings of the National Academy of Sciences of the USA, 107(43) (2007)
32. Johnson-Laird, P.N., Byrne, R.M.J.: Deduction. Erlbaum, Hillsdale (1991)
33. Polk, T.A., Newell, A.: Deduction as verbal reasoning. Psychol. Rev. 102, 533–566 (1995)
34. Rogers, Y., Rutherford, A., Bibby, P.A.: Models in the Mind: Theory, Perspective and Application, London (1992)
35. Markman, A.B., Gentner, D.: Thinking. Annual Review of Psychology 52, 223–247 (2001)
36. Johnson-Laird, P.N.: Mental models and thought. In: Holyoak, K.J., Morrisson, R.G. (eds.) The Cambridge Handbook of Thinking and Reasoning (2005)
37. Johnson-Laird, P.N., Byrne, R.M.J.: Conditionals: A theory of meaning, pragmatics, and inference. Psychological Review 109, 646–678 (2002)
38. Barrouillet, P., Gauffroy, C., Lecas, J.F.: Mental models and the suppositional account of conditionals. Psychological Review 115(3), 760–771 (2008)

39. Sasse, M.A.: Eliciting and Describing Users' Models of Computer Systems. Ph.D. Thesis, Computer Science, University of Birmingham (1997)
40. Gentner, D., Gentner, D.R.: Flowing waters or teemings crowds: mental models of electricity. In: Gentner, D., Stevens, A.L. (eds.) Mental Models, pp. 99–130. Lawrence Erlbaum Associate, Hilsdale (1983)
41. Carley, K., Palmquist, M.: Extracting, representing, and analyzing mental models. Social Forces 70(3), 601–636 (1992)
42. DeKleer, J., Brown, J.S.: Assumptions and ambiguities in mechanistics mental models. In: Gentner, D., Stevens, A.L. (eds.) Mental Models, pp. 155–190. Lawrence Erlbaum Associate, Hilsdale (1983)
43. Lederer, S., Mankoff, J., Dey, A.K.: Who Wants to Know What When? Privacy Preference Determinants in Ubiquitous Computing. In: CHI 2003. ACM, New York (2003)
44. Richter-Lipford, H., Besmer, A., Watson, J.: Understanding privacy settings in Facebook with an audience view. In: Proc. 1st Conf. on Usability Psych., & Sec., pp. 1–8. USENIX Association (2008)
45. PRIME WP06.1, HCI Guidelines, D06.1.f (2008), https://www.primeproject.eu/prime_products/reports/arch/pub_del_D06.1.f_ec_wp06.1_v1_final.pdf
46. Wästlund, E., Angulo, J., Fischer-Hübner, S.: Evoking comprehensive mental models of anonymous credentials. In: Camenisch, J., Kesdogan, D. (eds.) iNetSec 2011. LNCS, vol. 7039, pp. 1–14. Springer, Heidelberg (2012)
47. Camp, L.J.: Mental models of privacy and security. IEEE Technology and Society Magazine 28(3) (2009)
48. Simon, H.A., Chase, W.G.: Skill in chess. American Scientist 61, 394–403 (1973)
49. van der Veer, G.C.: Individual differences and the user interface. Ergonomics 32, 1431–1449 (1989)
50. Otter, M., Johnson, H.: Lost in hyperspace: metrics and mental models. Interacting with Computers 13, 1–40 (2000)
51. Kraiger, K., Salas, E.: Measuring mental models to assess learning during training. Paper presented at the Annual Meeting of the Society for Industrial/Organizational Psychology, San Francisco, CA (1993)
52. Diesner, J., Kumaraguru, P., Carley, K.M.: Mental models of privacy and security from interviews with Indians. In: 55th Annual Conference of the International Communication Association, New York, NY (2005)
53. Adams, A., Lunt, P., Cairns, P.: A qualitative approach to HCI research. In: Cairns, P., Cox, A.L. (eds.) Research Methods for Human-Computer Interaction, 1st edn., pp. 138–157. Cambridge University Press, Cambridge (2008)
54. Kinchin, I.M., Hay, D.B.: How a qualitative approach to concept map analysis can be used to aid learning by illustrating patterns of conceptual development. Educational Research 42(1) (2000)
55. Halford, G.S.: Children's Understanding: The Development of Mental Models. Lawrence Erlbaum, Hillsdale (1993)
56. Novak, J.D.: Learning, Creating and Using Knowledge: Concept Maps as Facilitative Tools in Schools and Corporations. Lawrence Erlbaum, Hillsdale (1998)
57. Novak, J.D., Gowin, D.B.: Learning How to Learn. Cambridge University Press, Cambridge (1984)
58. Wason, P.C.: Reasoning. In: Foss, B.M. (ed.) New Horizons in Psychology, Penguin, Harmondworth (1966)
59. Dolan, P., Hallsworth, M., Halpern, D., King, D., Metcalfe, R., Vlaev, I.: Influencing behaviour: The mindspace way. Journal of Economic Psychology 33(1), 264–277 (2012)