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A tale of two ambiguities: A conceptual overview of findings from economics and psychology

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Abstract
Ambiguity seems to be ... an ambiguous concept. While it has received attention from researchers from many disciplines, scientists from different backgrounds have put forward divergent, often vague and contrasting definitions of ambiguity. This conceptual impasse has somewhat obstructed cross-fertilization of insights across disciplines and has slowed the convergence of the results. Here, we examine the literature from economics and psychology, trace a map of intellectual knowledge on ambiguity in both disciplines and highlight open questions. Finally, we discuss some recent theoretical developments that could offer a unifying frame of reference for the study of ambiguity.

JEL Classification: D80 ; D81 ; D91

Keywords
ambiguity — uncertainty — ambiguity aversion — ambiguity intolerance

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Introduction

Ellsberg (1961) offered first empirical evidence that decision makers generally dislike ambiguous situations and alternatives characterized by vaguely defined probabilities. He called this behavior *ambiguity aversion* (AA). His findings stimulated vast research efforts in the economics literature, leading to ambiguity being conceived as a new dimension of the decision making process. Furthermore, the difference between risk and ambiguity has since then been firmly established (Trautmann and van de Kuilen, 2015, 89), and it seems to be supported with neuroscientific evidence, which indicates different neural substrates of the decision making processes in risk and ambiguity conditions (Hsu et al., 2005; Poudel et al., 2020). Nevertheless, the construct of ambiguity is still sometimes used interchangeably with uncertainty (De Groot and Thurik, 2018) thus creating some conceptual confusion. On the other hand, ambiguity has been introduced in the psychology literature by Frenkel-Brunswik in 1948 (Frenkel-Brunswik, 1948) and has been studied across many psychology disciplines ever since. These research endeavors have yielded a rich and multifaceted corpus of literature, consisting mainly of empirical studies, and containing some important insights on the nature of ambiguity as well as a multitude of measurement tools (Hillen et al., 2017, 63). However, as recently suggested (*ibidem*), the distributed nature of research, along with the lack of a shared underlying conceptual understanding of the phenomenon, has contributed to the creation of somewhat loosely knit web of knowledge. This situation leaves many essential questions still open, not least the inter-disciplinary one concerning the relation between the psychological and economics studies. In this article we present a brief review of the historical development of ambiguity studies in both economics and psychology and indicate the elements of confusion. Finally, we point out some recent conceptual developments which could offer a solid foundation for the future research and successful cross-fertilization of insights.

Ambiguity in Economics

According to the dominant model of individual economic behavior (the Subjective Expected Utility (SEU) theory; Savage, 1954), the decision makers are rational, and they always act based on their assessments of the outcomes of the decision process. The uncertainty about the outcomes is represented probabilistically in the form of subjective probabilities, measured through the elicitation of their behavioral consequences in the form of betting behavior (Ramsey, 1926; de Finetti, 1931, 1937). However, while allowing for the measurement of subjective probabilities, this approach does not take into consideration the degree of confidence that decision makers have in their models of probability, neither the instances when the subjects cannot form and use subjective probabilities, both aspects considered essential for the understanding of deci-

sion making (Knight, 1921; Keynes, 1937). To confine the research to betting experiments meant to ignore the fact that common, real-world decision making processes are usually based on vague, unknown or unknowable probabilities. Some degree of subjective uncertainty about our own probabilistic assessments is seemingly ubiquitous and Ellsberg (1961) was the first to provide experimental evidence that it plays an important role in the decision making. According to his findings (*idem*, 657), uncertain events can be classified into two categories: risky and ambiguous ones. In case of *risky* events, the probabilities of uncertain outcomes can be assessed using relative frequencies, or information about past experiences that help in forming a correct assessment of outcome probabilities. In case of *ambiguous* events, the decision maker has "scanty, unreliable or conflicting" (*idem*, 661) information about outcomes probabilities. In other words, risky events are situations with objective and known probabilities, while ambiguous events are situations where outcome probabilities are uncertain or unknown (Ghirardato et al., 2004). In what was to become known as the *Ellsberg paradox*, he showed that individuals systematically express preferences for risky over ambiguous choices, thus violating Savage's axioms. In other words, decision makers seem to manifest an aversion towards unknown probabilities as compared to the known ones.

These findings represent the cornerstone of an extensive net of empirical and theoretical literature, where the difference between decision maker's attitudes towards known and unknown probabilities has become the pillar of the definition of ambiguity aversion. Thus, in experimental settings ambiguity is operationalized by putting precisely and clearly defined outcome probabilities – the risk condition – against ambiguity condition (for a survey see Trautmann and van de Kuilen, 2015). The latter condition is designed in several ways, such as 1) *missing* outcome probabilities (Ellsberg's urns); 2) *vaguely specified* outcome probabilities, either *verbally* ("about 20%", "20% but unsure" etc.) or as a *range of probabilities* ("20 to 30%") (Kuhn, 1997); 3) through the measurement of the *premium* that individuals are willing to pay to avoid ambiguity (Cubitt et al., 2018). Empirical data has indicated that attitudes towards ambiguity depend on the likelihood of uncertain events, the outcome space, as well as the source that generates the uncertainty. More so, evidence supports the idea that individuals tend to be ambiguity-*averse* in the domain of gains, when the probability of winning is high, as in the two- and three-color Ellsberg tasks (Curley and Yates, 1989; Oechssler and Roomets, 2015), and ambiguity-*seeking* in the case of low likelihood gains (Chipman, 1960; Kahn and Sarin, 1988; Casey and Scholz, 1991; Bouchouicha et al., 2017). These findings have been replicated in various contexts, with experimental samples including non-student subjects (e.g., Butler et al., 2014; Dimmock et al., 2016), non-Western subjects (Engle-Warnick et al., 2011; Akay et al., 2012; Ross et al., 2012), children (Sutter et al., 2013), and monkeys (Hayden et al., 2010; Romain et al., 2021). Research on the validation of laboratory measure of ambiguity has also investigated some potential moderators of AA and results have singled out comparative ignorance and peer effects (among else).

Comparative ignorance magnifies AA when both risky and ambiguous events occur jointly. When an ambiguous act is presented separately (that is, without simultaneously referring to a risky act) its evaluation tends to be approximately equal to an equivalent risky one. However, when ambiguous and risky tasks are counterbalanced, different valuations emerge (Fox and Weber, 2002; Dimmock et al., 2016). Therefore, the nature of ambiguity attitudes appears to be *comparative* and the way the comparative ignorance effect seemingly works is through an increase of the evaluation for the risky act, rather than reducing value of the ambiguous one (Fox and Tversky, 1995; Chow and Sarin, 2001; Fox and Weber, 2002; Qiu and Weitzel, 2012). Therefore, ambiguity makes known probabilities look more desirable.

Peer effects, observable when individuals make choices jointly with others, also moderate ambiguity attitudes. Particularly, the observation of our own choice by others increases AA (Muthukrishnan et al., 2009; Trautmann et al., 2008). Similarly, people do not believe others to be ambiguity-neutral (Slovich and Tversky, 1974) and expect them to be ambiguity-averse (Kocher and Trautmann, 2013). Curiosly, group decisions seem not to be affected by AA (Keller et al., 2007). For example, Charness et al. (2013) show that in a group where subjects exhibit different degrees of ambiguity, ambiguity neutrality dominates.[1] These results contrast with the aforementioned peer effect, according to which ambiguity aversion is more socially acceptable.

AA has been documented in real-life situations and economic studies investigated its role in several applications, such as financial investments (Easley and O'Hara, 2009; Gollier, 2011; Attanasi et al., 2014; Dimmock et. al, 2016; d'Albis et al., 2020), legal effectiveness (Duff, 1999; Teitelbaum, 2007; Corcos et al., 2020), medical decisions (Berger et al., 2013; Hoy et al., 2014), wage-setting and contracting (Hogart and Kunreuther, 1989), voting (Shepsle, 1972; Aragonès and Neeman, 2000), and macroeconomic policymaking (Masolo and Monti, 2021). Furthermore, Farber (2011) has explored how ambiguity affects optimal regulation of controversial policy issues, such as climate change through emission reduction, nanotechnology regulation, long-lived nuclear waste treatment, and financial instability regulation. Empirical research shows that ambiguity has grown dramatically since the beginning of the COVID-19 pandemic (Alifano et al., 2020). This has posed a significant challenge for policymakers who needed to find a proper balance between health protection and the avoidance of social and economic costs caused by closures. As pointed out by Berger et al. (2021, 3) "high scientific uncertainty, with minimal quality evidence, and potential disagreements among experts and models" were and still are the dominant features during the pandemic. A large branch of the economic studies exploring the potential effects

[1] See also Keck et al. (2014).

of ambiguity on individual behaviors, policymakers' decision and outcomes of various contentive measures has unfolded since the start of the pandemic.[2]

Among else, in the aforementioned study by Berger et al. (2021), the authors have examined the choice of policymakers to close schools and the optimal length of the closing period during the first wave of the COVID-19 pandemic. They have showed how the optimal length period of school closures changes under alternative decisional rules taking into account the ambiguity of the economic and social environment (subjective expected utility rule, smooth ambiguity rule, max-min rule, multiple priors rule). They have also underlined the importance, for policymakers, of adopting transparent and coherent decisional rules during the pandemic to face the pervasive ambiguity in the society.

On the other hand, theoretical literature has since incorporated ambiguity averse preferences in subjective settings. For instance, Schmeidler (1989) and Gilboa and Schmeidler (1989) modified Savage's (1954) SEU model to incorporate AA, by relaxing the Sure-Thing principle and adding an ambiguity aversion postulate. Also, in the aforementioned work, Schmeidler (1989) provided an alternative explanation for the Ellsberg's paradox, characterizing the Choquet-expected utility, based on the idea that beliefs are defined using capacity and may be non-additive. Moreover, according to Gilboa and Schmeidler (1989), individuals have multiple prior subjective probability distributions over the set of outcomes and choose the alternative that maximizes the minimum expected utility over these distributions. Klibanoff et al. (2005) have also proposed a modified SEU model, separating ambiguity, measured as a characteristic of the decision maker's *subjective beliefs*, and ambiguity attitude, a characteristic of the decision maker's *tastes*. Maccheroni et al. (2006) introduce variational preferences, a utility function capturing both the individual attitude towards risk defined over outcomes and an ambiguity index defined over the set of probability distributions. Variational preferences are a very broad class of preferences encompassing not only expected utility preferences and multiplier preferences, but they included as special cases the aforementioned maxmin utility function introduced by Gilboa and Schmeidler (1989), the Markovitz mean-variance preferences (1952) but also the Hansen and Sargent (2001) multiplier preferences. Theoretical research has supported the positive value of information for ambiguity averse subjects, when it reduces ambiguity. Among others, interesting contributions are represented by the works of Quiggin (2007), using Machina's (2004) concept of almost-objective acts and Attanasi and Montesano (2012), using Choquet Expected Utility model.

Despite the seemingly ubiquitous convergence of economic research on the conception of ambiguity as reflecting the difference in subject's decisions and beliefs towards known versus unknown probabilities, Abdellaoui et al. (2011) challenged this view and explored the *terra incognita* beyond this comparison. They discovered that not only decision makers behave diversely under risk and ambiguity conditions, but they also manifest distinct and stable attitudes towards different *ambiguous* events, where no probabilities are specified whatsoever. Empirical data outlining the emergence of clear and coherent patterns of behavior in separate ambiguity conditions essentially excluded the noise as a possible cause and indicated the existence of different ambiguity attitudes. To construct a theoretical model capable of explaining this diversity, the authors build upon the idea of *source of uncertainty*, initially proposed by Tversky and co-authors (Tversky and Kahneman, 1992; Fox and Tversky, 1995) and subsequently explored in Chew et al. (2008) and Ergin and Gul (2009).[3] In their model, the source of uncertainty is defined as "groups of events that are generated by the same mechanism of uncertainty, which implies that they have similar characteristics" (Abdellaoui et al., 2011, 696). For instance, a transparent urn from which a ball is drawn represents one source of uncertainty, with an opaque urn being a different and distinct one. Generally, agents are willing to exchange a bet *within* one source but not *between* the sources. Correspondingly, while future trends of stocks cannot be predicted neither in domestic nor in international financial markets, subjects systematically express preferences towards investing in home markets, as if the ambiguity about them was somewhat less aversive.[4] In other words, while the decision makers express a "uniform degree of ambiguity throughout the source" (*idem*, 717), they tend to exhibit *different* attitudes towards *different* sources. These findings allow for a reconceptualization of ambiguity attitudes as instances of source preferences and subsequent analyses indicate that this model has significantly higher predictive power in modelling decision making under uncertainty than the traditional ones (Kothiyal et al., 2014).

Likewise, source models generally subsume the events with known probabilities under the condition of risk (i.e., representing a single, uniform source of uncertainty) against which the attitudes towards different sources of ambiguity are evaluated (as in Abdellaoui et al., 2011). However, first in Halevy (2007) and then in Armantier and Treich (2016), this assumption on the uniformity of the risk attitudes is called into question. For instance, in the latter study authors have explored behavioral patterns in different risk conditions, and they found that in a situation where the outcome depends on a simultaneous draw from two urns of known composition – the so-called "complex risk" condition – the subjects expressed preferences systematically different from the ones in "simple risk" condition, represented by the draw from a single urn with known probabilities. In other words, behavior in distinct situations with known outcome probabilities is not always

[2] See, among others, Anderson et al. (2020); Cancryn (2020); Chater (2020); Emanuel et al. (2020); Lazzerini and Putoto (2020); Rucker et al. (2020).

[3] See Waker (2010), Attanasi (2011), de Palma et al. (2018) for a survey.

[4] The consequence of this preference is a substantial portfolio underdiversification, a phenomenon known as home bias (French and Poterba, 1991)

homogenous. Indeed, there are significant differences in risk attitudes towards events perceived as simple versus ones seen as complex. Authors also found evidence suggesting a strong correlation between subjects' beliefs and decisions in "complex risk" and the ambiguity conditions, as first reported by Halevy (2007), and in Abdellaoui et al. (2015). Thus, these findings imply that ambiguity attitudes cannot be unequivocally defined against the "rich domain of risk" (Armantier and Treich, 2016, 1).

These newly discovered territories of the uncertainty landscape have challenged the usual economic modelizations of decision making under uncertainty and ambiguity. Additionally, these results entail that any future attempt aimed at characterizing the decision making processes in these situations should include a further differentiation beyond the dichotomy of known versus unknown probabilities that characterized it since Ellsberg (1961).

Ambiguity in Psychology

The concept of ambiguity in psychology literature appeared as a constituent of *Ambiguity Intolerance* (AI), a construct defined by Frenkel-Brunswik as a "tendency to resort to black-white solutions, to arrive at premature closure as to valuative aspects, often at the neglect of reality, and to seek for unqualified and unambiguous overall acceptance and rejection of other people" (1949, 115). AI, as a "perceptual and emotional personality variable" (Frenkel-Brunswik, 1948), was firstly embraced by social psychology researchers. Initially, most of them focused their efforts on the construction of the instruments capable of estimating the individual level of AI. One among the most cited and used is Budner's Tolerance for Ambiguity Scale (1962). Martin and Westie (1959), Rydell and Rosen (1966) and Mac Donald (1970) also developed their scales, but all these tests were troubled by "low internal reliability and absence of adequate validity evidence" (Norton, 1975). Furthermore, in the light of classical state-trait difference in psychology (Allport, 1966; Fridhandler, 1986; Zuckerman, 1983; Geiser et al., 2017) we must note that all these tests were treating the ambiguity construct as part of a *trait* variable, that is, as a stable individual tendency to perceive and react to ambiguity in a certain way across similar contexts. On the contrary, they did not take into consideration the *state* ambiguity, that is, behavioral differences arising from the individual's encounter with the specific, concrete situation in a particular moment of time.

Literature research in the various psychology domains reveals an extensive and diversified network structure of scientific knowledge. AI was examined both as a dependent and independent variable, in relation to multiple, cross-cultural and inter-disciplinary phenomena, among others authoritarianism and leadership preference (Bhushan, 1970), authoritarianism and locus of control (Shavit, 1975), sociopolitical ideology (Sidanius, 1978), cognitive complexity and sex-role orientation (Rotter and O'Conner, 1982), dissonance (Shaffer et al., 1974), depression (Andersen and Schwartz, 1992), mindfulness (Ie et al., 2012), anxiety (Buhr and Dugas, 2006), job performance (Gregersen and Morrison, 1998), effectiveness of leadership (Black, 2005) and acquisition of management skills (Furuya et al., 2009). This paints a picture very different from the one seen in the economics domain, where the focus was exclusively on the role of ambiguity in specific decision making scenarios. Furthermore, in economics literature we have found a substantial convergence among studies regarding the methodology and experimental approach used. On the other hand, in the psychology literature researchers from different backgrounds have used a variety of approaches for eliciting ambiguity as part of AI measurement, including intelligence tests, optical illusions and self-report questionnaires, thus generating a confusion about the very nature of AI and its appropriate assessment. More so, this approach heterogeneity resulted in the lack of convergence in research findings (Herman et al., 2010; Cavatorta and Schröder, 2019) and lead Kirton (1981) to assert that the construct has become overextended. Others (e. g. Durrheim and Foster, 1997; Durrheim, 1998) went further and questioned the nature of AI as a stable individual trait. Furthermore, the very definition of AI, despite substantial research efforts, was lacking conceptual clarity and coherence. Already Norton (1975) found 120 different meanings of the term ambiguous in the existing literature on AI.

Furthermore, this conceptual fog seems to have only intensified since, with the emergence of new, very similar constructs. In the field of clinical psychology, an attempt to offer a new theoretical model of Generalized Anxiety Disorder entailed the development of a concept called *Intolerance of Uncertainty* (IU). The IU represented "cognitive, emotional and behavioral reactions to uncertainty in everyday life situations" (Freeston et al., 1994, 792). Because of its similarity to the Frenkel-Brunswik's conceptualization of AI, the IU was later revised to reflect "an excessive tendency to find uncertain situations stressful and upsetting, to believe that unexpected events are negative and should be avoided, and to think that being uncertain about the future is unfair" (Dugas et al., 2005). Nevertheless, it seems that there is still a significant degree of confusion between the constructs of AI and IU. The two terms are frequently used interchangeably and there are cases of studies initially designated to measure the one and effectively evaluating the other, as reported in Rosen et al. (2014) and Hillen et al. (2017). While there is some evidence suggesting that adolescents display different levels of AI and IU in decision making tasks (van Den Bos and Hertwig, 2017), studies that aimed to establish theoretical boundaries of the two constructs are few. For instance, Grenier et al. (2005) have advanced a distinction based on temporal reference. According to them, the AI refers to a discomfort provoked by the ambiguity of the here-and-now, and the IU concerns the apprehension towards the uncertainty of the future events. The experimental evidence, however, did not confirm this hypothesis (Buhr and Dugas, 2006).

Moreover, two other, very similar concepts appeared on

the scientific landscape – the *Need for Closure* (Kruglanski, 1990; Webster and Kruglanski, 1994; Kruglanski and Webster, 1996; Kruglanski et al., 2009) and *Uncertainty Orientation* (Sorrentino and Short, 1986). The former represents individual tendency to seek a "firm answer to a question and an aversion toward ambiguity" (Kruglanski and Webster, 1996, 264), while the latter indicates a particular individual information processing style in resolving the situations of uncertainty (Sorrentino and Short, 1986). Nevertheless, both Need for Closure and Uncertainty Orientation present a significant overlap with AI and IU (see Rosen et al., 2014; Hillen et al., 2017).

Therefore, the study of ambiguity in the psychology literature seemingly displays a lack of clarity regarding the conceptual boundaries and a potential convergence between various constructs. This apparent impasse has motivated significant research efforts towards clarification and conceptual differentiation, as testified by the number of recent literature reviews (Grenier et al., 2005; Berenbaum et al., 2008; Birrell et al., 2011; Furnham and Marks, 2013; Rosen et al., 2014; Hillen et al., 2017). Furthermore, there is still the inter-disciplinary question regarding the extent of the overlap between the AA as defined in economics and AI as a psychological construct. A recent paper from Schröder and Gilboa Freedman reports experimental findings that "show a complex picture of the relation between economic and psychological measures" (2020, 74). Considering previous results on the influence of the operationalization of ambiguity on experimental results (Highhouse, 1994), the authors' hypothesis that ambiguity operationalizations in economics and psychology seem to capture at least partly different constructs does not come as a surprise. Additionally, recent neuroscientific evidence signals the possibility of different neural underpinnings of the constructs of AI and AA (Tanaka et al., 2015). However, the scarcity of available evidence means that the question of the nature of this relationship remains essentially open.

Recent theoretical developments and potential future paths

Based on this brief literature appraisal, it seems that theoretical foundations of the studies on ambiguity have not yet benefited from the contemporary cross-fertilization of insights between psychology and economics. In this section we want to highlight some of the recent developments that we consider potentially useful for a construction of shared understanding of the aforementioned phenomena. Particularly, we would like to point out two recent theoretical proposals which could represent an effective starting point for the development of a unifying, logically coherent, and empirically based theoretical framework for the study of ambiguity and uncertainty.

The first one is rooted in the works of decision scientist Smithson, (Smithson, 1989; 1999), who defined *ignorance* as a state of mind of "not knowing what one doesn't know" (1989, 6). On the other hand, *meta-ignorance* is a conscious awareness of one's ignorance about something, i.e., a state of knowing what one doesn't know. Therefore, meta-ignorance, or rather *uncertainty* (Smithson, 1999), is a "metacognition representing a particular kind of explicit knowledge – an acknowledgment of what one does not know, but also that one does not know" (Anderson et al., 2019, 2). Here, as highlighted by Anderson et al. (2019), it is important to stress two aspects: first, uncertainty and ignorance are not equal; second, both of these constructs refer to the psychological, *subjective* states of an individual, rather that to *objective* features of the external world. This viewpoint was then incorporated in Krohne's works (1989, 2011) in the field of health research, where the author distinguishes uncertainty, a *subjective* state, from ambiguity, which is seen as a *characteristic of the information* one has. With this, Hillen et al. (2017), construe uncertainty as an *overarching* construct pertinent to the subject and its mental state. On the other hand, ambiguity is conceived as a *subordinate* phenomenon describing the information one has, namely, its characteristics such as the lack of reliability, credibility and adequacy. In essence, perception of missing, imprecise or conflicting (in other words, ambiguous) information by the subject gives rise to the subjective state of uncertainty. Thus, the authors consider ambiguity as one potential *source* of uncertainty, with other potential sources being risk and complexity. However, we must note that the terminological match with the aforementioned conceptions based on source preferences does not entail the conceptual overlap - the term source in this case is used more broadly as a cause or a subset of uncertainty related to decision making and not as "a group of events that are generated by the same mechanism of uncertainty" as intended by Abdellaoui et al. (2011, 696).

Secondly, Enke and Graeber (2019) advanced a theoretical description of a possible mechanism underlying systematic deviations from rationality such as ambiguity and complex risk aversion. Their starting point is the understanding that elaboration of the decision problem is not always straightforward and the difficulties and imperfections in the cognitive processing can subsequently shape our choices and beliefs. Thinking through probabilities is often difficult and we are not invariably sure of our judgments and decisions. Assessing and retrieving information from memory, synthetizing all the available information into probabilities, and then combining personal preferences, probabilities and utils are cognitively demanding processes and they are not immune to errors and imperfections. In other words, the individual cognitive elaboration of probabilities is often *noisy*, and we are usually aware of this (non)optimality of our reasoning. This awareness gives rise to *cognitive uncertainty*, which is a "subjective uncertainty about what the optimal action or solution to a decision problem is" (Enke and Graeber, 2019, 1). Finally, the cornerstone of this model is the idea of the positive link between the cognitive uncertainty and the bias in preferences and decisions. In other words, the higher the perceived uncertainty, the more we will tend to deviate away from the rational optimum. This hypothesis has received strong empirical support, indicating a

robust relationship between subjective uncertainty and biases across different domains and tasks. Authors have showed how the perceived uncertainty modulates behavioral responses to various features of the decision problem, leading to the well documented behavioral patterns. For instance, they found that canonically defined complex and ambiguous lotteries reliably induced higher levels of cognitive uncertainty. Also, authors documented a significant and relatively stable variation of individual cognitive uncertainty across different tasks and domains, suggesting the existence of a trait component of the found behavioral variance. Furthermore, detected systematic diversification across participants and tasks seems to indicate a functional dependence of the perception of uncertainty on both the features of the context and individual traits.[5] In synthesis, by endogenizing the uncertainty parameter, authors have constructed a model with strong explanatory capabilities as well as high predictive power. Moreover, their empirical results show significant convergence with the recent insights coming from psychological sciences describing the individual behaviors as results of a state-trait interaction.

The two described models present different analogies and offer somewhat complementary inputs for a clear definition of constructs of ambiguity and uncertainty. While the Hillen et al. (2017) lay the foundation for a coherent and unequivocal conceptual differentiation between the two constructs, Enke and Graeber (2019) put forward an empirically based hypothesis describing their functional relationship. The authors in both cases advance an explanation construed on the metacognitive notion of (cognitive) uncertainty and its different individual and situational antecedents (among which, ambiguity and complexity). We must underline that, while there is certainly a substantial degree of overlap between the conceptual foundations of these two research streams, they are not to be equated. Nonetheless, their aforementioned complementarity could, in our view, represent a viable platform for the future research, aimed at exploring possibilities of the fruitful integration of the studies on ambiguity in domains of psychology and economics. Also, a cross-pollination between two literatures could potentially help in better understating the real-world determinants of ambiguity as a state and the personality correlates of the trait ambiguity as conceived in the AA and AI. Finally, it could further contribute to the elaboration of models of behavior based on the state-trait interaction, which in turn could offer a more comprehensive explanation of behavioral variance than the more traditional ones based on average trait values (Dan et al., 2020, 154).

Finally, we would like to indicate another interesting and potentially useful source of insights – the studies on curiosity. This research tradition is concerned with information-seeking in the ambiguous situations, a behavioral aspect that is orthogonal to the ambiguity aversion. The proximity of the two research domains is noted by Loewenstein (1994, 83) who stated that the only difference between the ambiguity and the curiosity literature seemed to be in their focus – in the ambiguous situations, the former studied how and why people avoid making (uninformed) decisions whereas the latter is concerned instead with the information-seeking behaviors. Furthermore, Loewenstein's view of curiosity as aroused by "information gaps" (1994, 87) is strikingly similar to Smithson's (1989) theory of uncertainty. Ambiguous situations can provoke cognitive "incongruity", a misalignment between our expectations and the reality, or point out a "gap" in our knowledge about the situation (Loewenstein, 1994, 82). This (depending on the magnitude of the ambiguity) can motivate either information-seeking (curiosity) or avoidance (ambiguity aversion). When the gaps in our information are perceived as relatively small and potentially closable with the available information, curiosity is aroused. On the other hand, when the information gap exceeds a certain threshold, avoidance behaviors are activated. In our view, the conceptualizations of curiosity could shed further light on some aspects of the aforementioned phenomena including uncertainty and ambiguity.

[5] See also Slovic (2010) and Attanasi (2012).

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References

Abdellaoui, M., A. Baillon, L. Placido, and P. P. Wakker (2011). The Rich Domain of Uncertainty: Source Functions and Their Experimental Implementation. *American Economic Review 101*(2), 695–723.

Abdellaoui, M., P. Klibanoff, and L. Placido (2015). Experiments on Compound Risk in Relation to Simple Risk and to Ambiguity. *Management Science 61*(6), 1306–1322.

Akay, A., P. Martinsson, H. Medhin, and S. T. Trautmann (2012). Attitudes toward uncertainty among the poor: An experiment in rural ethiopia. *Theory and Decision 73*, 453–464.

Alifano, M., G. Attanasi, F. Iannelli, F. Cherikh, and A. Iannelli (2020). COVID-19 pandemic: a European perspective on health economic policies. *Journal of Behavioral Economics for Policy 4*, 35–43.

Allport, G. W. (1966). Traits revisited. *American Psychologist 21*, 1–10.

Andersen, S. M. and A. H. Schwartz (1992). Intolerance of Ambiguity and Depression: A Cognitive Vulnerability Factor Linked to Hopelessness. *Social Cognition 10*, 271–298.

Anderson, E. C., R. N. Carleton, M. Diefenbach, and P. K. J. Han (2019). The Relationship Between Uncertainty and Affect. *Frontiers in Psychology 10*.

Anderson, R. M., H. Heesterbeek, D. Klinkenberg, and T. D. Hollingsworth (2020). How will country-based mitigation measures influence the course of the COVID-19 epidemic? *The Lancet 395*, 931–934.

Aragonès, E. and Z. Neeman (2000). Strategic ambiguity in electoral competition. *Journal of Theoretical Politics 12*, 183–204.

Armantier, O. and N. Treich (2016). The rich domain of risk. *Management Science 62*, 1954–1969.

Attanasi, G. (2011). Prospect Theory: For risk and ambiguity, Peter P. Wakker. Cambridge University Press, Cambridge, UK (2010). 503 and xiii pp.,£ 29.99, ISBN: 978-0-521-74868-1. *Journal of Economic Psychology 32*(3), 538–540.

Attanasi, G. (2012). The Feeling of Risk: New perspectives on Risk Perception, Paul Slovic. Earthscan, London, UK (2010). 428 and xxviii pp., £29.99, ISBN 978-1-849-71148-7. *Journal of Economic Psychology 33*(4), 914–917.

Attanasi, G., C. Gollier, A. Montesano, and N. Pace (2014). Eliciting ambiguity aversion in unknown and in compound lotteries: a smooth ambiguity model experimental study. *Theory and Decision 77*, 485–530.

Attanasi, G. and A. Montesano (2012). The price for information about probabilities and its relation with risk and ambiguity. *Theory and Decision 73*, 125–160.

Berenbaum, H., K. Bredemeier, and R. J. Thompson (2008). Intolerance of uncertainty: Exploring its dimensionality and associations with need for cognitive closure, psychopathology, and personality. *Journal of Anxiety Disorders 22*, 117–125.

Berger, L., N. Berger, V. Bosetti, I. Gilboa, C. J. Lars Hansen, M. Marinacci, and R. Smith (2021). Rational policymaking during a pandemic. *Proceedings of the National Academy of Sciences 118*(4).

Berger, L., H. Bleichrodt, and L. Eeckhoudt (2013). Treatment decisions under ambiguity. *Journal of Health Economics 32*.

Bhushan, R. (1970). Intolerance of ambiguity in conformists and nonconformists. *Manas 17*, 35–39.

Birrell, J., K. Meares, A. Wilkinson, and M. H. Freeston (2011). Toward a definition of intolerance of uncertainty: A review of factor analytical studies of the intolerance of uncertainty scale. *Clinical Psychology Review 31*, 1198–1208.

Black, J. S. (2005). The Mindset of Global Leaders: Inquisitiveness and Duality. In W. H. Mobley and E. Weldon (Eds.), *Advances in Global Leadership*, pp. 181–200. Bingley: Emerald Group Publishing Ltd.

Bouchouicha, R., P. Martinsson, H. Medhin, and F. M. Vieider (2017). Stake effects on ambiguity attitudes for gains and losses. *Theory and Decision 83*, 19–35.

Budner, S. N. Y. (1962). Intolerance of ambiguity as a personality variable. *Journal of Personality 30*, 29–50.

Buhr, K. and M. J. Dugas (2006). Investigating the construct validity of intolerance of uncertainty and its unique relationship with worry. *Journal of Anxiety Disorders 20*, 222–236.

Butler, J. V., L. Guiso, and T. Jappelli (2014). The role of intuition and reasoning in driving aversion to risk and ambiguity. *Theory and Decision 77*, 455–484.

Cancryn, A. (2020, 4). How Overly Optimistic Modeling Distorted Trump Team's Coronavirus Response. Available at: https://www.politico.com/news/2020/04/24/trump-coronavirus-model-207582.

Casey, J. T. and J. T. Scholz (1991). Beyond Deterrence: Behavioral Decision Theory and Tax Compliance. *Law & Society Review 25*, 821–844.

Cavatorta, E. and D. Schröder (2019). Measuring ambiguity preferences: A new ambiguity preference survey module. *Journal of Risk and Uncertainty*, 71–100.

Charness, G., E. Karni, and D. Levin (2013). Ambiguity attitudes and social interactions: An experimental investigation. *Journal of Risk and Uncertainty 46*, 1–25.

Chater, N. (2020). Facing up to the uncertainties of COVID-19. *Nature human behaviour 4*.

Chew, S. H., K. K. Li, R. Chark, and S. Zhong (2008). Source preference and ambiguity aversion: models and evidence from behavioral and neuroimaging experiments. In D. Houser and K. McCabe (Eds.), *Neuroeconomics (Advances in Health Economics and Health Services Research)*, Volume 20, pp. 179–201. Emerald Group Publishing Ltd.

Chipman, J. S. (1960). Stochastic choice and subjective probability. In D. Willmer (Ed.), *Decision, Values, and Groups*, pp. 70–95. New York: Pergamon Press.

Chow, C. C. and R. K. Sarin (2001). Comparative Ignorance and the Ellsberg Paradox. *Journal of Risk and Uncertainty 22*, 129–139.

Corcos, A., C. Montmarquette, and F. Pannequin (2020). How the demand for insurance became behavioral. *Journal of Economic Behavior & Organization 180*, 590–595.

Cubitt, R., G. van de Kuilen, and S. Mukerji (2018). The strength of sensitivity to ambiguity. *Theory and Decision 85*, 275–302.

Curley, S. P. and J. F. Yates (1989). An empirical evaluation of descriptive models of ambiguity reactions in choice situations. *Journal of Mathematical Psychology 33*, 397–427.

Dan, O., M. Leshkowitz, and R. R. Hassin (2020). On clickbaits and evolution: curiosity from urge and interest. *Current Opinion in Behavioral Sciences 35*.

de Finetti, B. (1931). Sul significato soggettivo della probabilità. *Fundamenta Mathematicae 17*, 298–329.

de Finetti, B. (1937). La prévision: Ses lois logiques, ses sources subjectives. *Annales de l'Institut Henri Poincaré 7*, 1–68.

Dimmock, S. G., R. Kouwenberg, O. S. Mitchell, and K. Peijnenburg (2016). Ambiguity aversion and household portfolio choice puzzles: Empirical evidence. *Journal of Financial Economics 119*, 559–577.

Dimmock, S. G., R. Kouwenberg, and P. P. Wakker (2016). Ambiguity attitudes in a large representative sample. *Management Science 62*, 1363–1380.

Donald, A. P. M. (1970). Revised Scale for Ambiguity Tolerance: Reliability and Validity. *Psychological Reports 26*, 791–798.

Duff, P. (1999). The Scottish Criminal Jury: A Very Peculiar Institution. *Law and Contemporary Problems 62*, 173–201.

Dugas, M. J., M. Hedayati, A. Karavidas, K. Buhr, K. Francis, and N. A. Phillips (2005). Intolerance of uncertainty and information processing: Evidence of biased recall and interpretations. *Cognitive Therapy and Research 29*, 57–70.

Durrheim, K. (1998). The relationship between tolerance of ambiguity and attitudinal conservatism: A multidimensional analysis. *European Journal of Social Psychology 28*, 731–753.

Durrheim, K. and D. Foster (1997). Tolerance of ambiguity as a content specific construct. *Personality and Individual Differences 22*, 741–750.

d'Albis, H., G. Attanasi, and E. Thibault (2020). An experimental test of the under-annuitization puzzle with smooth ambiguity and charitable giving. *Journal of Economic Behavior & Organization 180*, 694–717.

Easley, D. and M. O'Hara (2009). Ambiguity and nonparticipation: The role of regulation. *Review of Financial Studies 22*, 1817–1843.

Ellsberg, D. (1961). Risk, Ambiguity, and the Savage Axioms. *Quarterly Journal of Economics 75*, 643–669.

Emanuel, E. J., G. Persad, R. Upshur, B. Thome, M. Parker, A. Glickman, C. Zhang, C. Boyle, M. Smith, and J. P. Phillips (2020). Fair Allocation of Scarce Medical Resources in the Time of Covid-19. *New England Journal of Medicine 382*.

Engle-Warnick, J., J. Escobal, and S. Laszlo (2011). Ambiguity Aversion as a Predictor of Technology Choice: Experimental Evidence from Peru. *SSRN Electronic Journal*.

Enke, B. and T. Graeber (2019). Cognitive Uncertainty. Working Paper 5694, National Bureau of Economic Research.

Ergin, H. and F. Gul (2009). A theory of subjective compound lotteries. *Journal of Economic Theory 144*, 899–929.

Farber, D. A. (2011). Uncertainty. Working paper, Georgetown Law Journal.

Fox, C. R. and A. Tversky (1995). Ambiguity aversion and comparative ignorance. *The Quarterly Journal of Economics 110*, 585–603.

Fox, C. R. and M. Weber (2002). Ambiguity aversion, comparative ignorance, and decision context. *Organizational Behavior and Human Decision Processes 88*, 476–498.

Freeston, M. H., J. Rhéaume, H. Letarte, M. J. Dugas, and R. Ladouceur (1994). Why do people worry? *Personality and Individual Differences 17*, 791–802.

French, K. R. and J. M. Poterba (1991). Investor diversification and international equity markets. *The American Economic Review 81*, 222–226.

Frenkel-Brunswik, E. (1948). Tolerance toward ambiguity as a personality variable. *American Psychologist 3*, 385–401.

Frenkel-Brunswik, E. (1949). Intolerance of ambiguity as an emotional and perceptual personality variable. *Journal of Personality 18*, 108–143.

Fridhandler, B. M. (1986). Conceptual Note on State, Trait, and the State-Trait Distinction. *Journal of Personality and Social Psychology 50*, 169–174.

Furnham, A. and J. Marks (2013). Tolerance of Ambiguity: A Review of the Recent Literature. *Psychology 04*, 717–728.

Furuya, N., M. J. Stevens, A. Bird, G. Oddou, and M. Mendenhall (2009). Managing the learning and transfer of global management competence: Antecedents and outcomes of Japanese repatriation effectiveness. *Journal of International Business Studies 40*, 200–215.

Geiser, C., T. Götz, F. Preckel, and P. A. Freund (2017, 7). States and Traits. *European Journal of Psychological Assessment 33*, 219–223.

Ghirardato, P. (2004). Defining ambiguity and ambiguity attitude. In I. Gilboa (Ed.), *Uncertainty in Economic Theory: A collection of essays in honor of David Schmeidler's 65th birthday*, pp. 36–45. London: Routledge.

Gilboa, I. and D. Schmeidler (1989). Maxmin expected utility with non-unique prior. *Journal of Mathematical Economics 18*, 141–153.

Gollier, C. (2011). Portfolio Choices and Asset Prices: The Comparative Statics of Ambiguity Aversion. *Review of Economic Studies 78*(4), 1329–1344.

Gregersen, H. and A. Morrison (1998). Developing Leaders for the Global Frontier. *Sloan Management Review 40*, 21–32.

Grenier, S., A. M. Barrette, and R. Ladouceur (2005). Intolerance of uncertainty and intolerance of ambiguity: Similarities and differences. *Personality and Individual Differences 39*, 593–600.

Groot, K. D. and R. Thurik (2018). Disentangling risk and uncertainty: When risk-taking measures are not about risk. *Frontiers in Psychology 9*.

Halevy, Y. (2007). Ellsberg revisited: An experimental study. *Econometrica 75*, 503–536.

Hansen, L. P. and T. J. Sargent (2001). Robust Control and Model Uncertainty. *American Economic Review 91*, 60–66.

Hayden, B. Y., S. R. Heilbronner, and M. L. Platt (2010). Ambiguity aversion in rhesus macaques. *Frontiers in Neuroscience 4*.

Herman, J. L., M. J. Stevens, A. Bird, M. Mendenhall, and G. Oddou (2010). The Tolerance for Ambiguity Scale: Towards a more refined measure for international management research. *International Journal of Intercultural Relations 34*.

Highhouse, S. (1994). A verbal protocol analysis of choice under ambiguity. *Journal of Economic Psychology 15*, 621–635.

Hillen, M. A., C. M. Gutheil, T. D. Strout, E. M. Smets, and P. K. Han (2017). Tolerance of uncertainty: Conceptual analysis, integrative model, and implications for healthcare. *Social Science & Medicine 180*, 62–75.

Hogarth, R. M. and H. Kunreuther (1989). Risk, ambiguity, and insurance. *Journal of Risk and Uncertainty 2*, 5–35.

Hoy, M., R. Peter, and A. Richter (2014). Take-up for genetic tests and ambiguity. *Journal of Risk and Uncertainty 48*, 111–133.

Hsu, M., M. Bhatt, R. Adolphs, D. Tranel, and C. F. Camerer (2005). Neuroscience: Neural systems responding to degrees of uncertainty in human decision-making. *Science 310*, 1680–1683.

Ie, A., C. H. Haller, E. J. Langer, and D. S. Courvoisier (2012). Mindful multitasking: The relationship between mindful flexibility and media multitasking. *Computers in Human Behavior 28*, 1526–1532.

Kahn, B. E. and R. K. Sarin (1988). Modeling Ambiguity in Decisions Under Uncertainty. *Journal of Consumer Research 15*, 265–272.

Keck, S., E. Diecidue, and D. V. Budescu (2014). Group decisions under ambiguity: Convergence to neutrality. *Journal of Economic Behavior & Organization 103*, 60–71.

Keller, L. R., R. K. Sarin, and J. Sounderpandian (2007). An examination of ambiguity aversion: Are two heads better than one? *Judgment and Decision Making 2*, 390–397.

Keynes, J. M. (1937). The general theory of employment. *Quarterly Journal of Economics 51*, 209–223.

Kirton, M. J. (1981). A Reanalysis of Two Scales of Tolerance of Ambiguity. *Journal of Personality Assessment 45*, 407–414.

Klibanoff, P., M. Marinacci, and S. Mukerji (2005). A smooth model of decision making under ambiguity. *Econometrica 73*, 1849–1892.

Knight, F. H. (1921). *Risk, uncertainty and profit*. New York, NY: Hart, Schaffner and Marx.

Kocher, M. G. and S. T. Trautmann (2013). Selection into auctions for risky and ambiguous prospects. *Economic Inquiry 51*, 882–895.

Kothiyal, A., V. Spinu, and P. P. Wakker (2014). An experimental test of prospect theory for predicting choice under ambiguity. *Journal of Risk and Uncertainty 48*, 1–17.

Krohne, H. W. (1989). The concept of coping modes: Relating cognitive person variables to actual coping behavior. *Advances in Behaviour Research and Therapy 11*, 235–248.

Krohne, H. W. and M. Hock (2011). Anxiety, coping strategies, and the processing of threatening information: Investigations with cognitive-experimental paradigms. *Personality and Individual Differences 50*, 916–925.

Kruglanski, A. W. (1990). Lay Epistemic Theory in Social-Cognitive Psychology. *Psychological Inquiry 1*, 181–197.

Kruglanski, A. W., M. Dechesne, E. Orehek, and A. Pierro (2009). Three decades of lay epistemics: The why, how, and who of knowledge formation. *European Review of Social Psychology 20*, 146–191.

Kruglanski, A. W. and D. M. Webster (1996). Motivated Closing of the Mind: "Seizing" and "Freezing". *Psychological Review 103*, 263–283.

Kuhn, K. M. (1997). Communicating uncertainty: Framing effects on responses to vague probabilities. *Organizational Behavior and Human Decision Processes 71*(1), 55–83.

Lazzerini, M. and G. Putoto (2020). COVID-19 in Italy: momentous decisions and many uncertainties. *The Lancet. Global Health 8*, e641–e642.

Loewenstein, G. (1994). The Psychology of Curiosity: A Review and Reinterpretation. *Psychological Bulletin 116*, 75–98.

Maccheroni, F., M. Marinacci, and A. Rustichini (2006). Ambiguity Aversion, Robustness, and the Variational Representation of Preferences. *Econometrica 74*(6), 1447–1498.

Machina, M. J. (2004). Almost-objective uncertainty. *Economic Theory 24*, 1–54.

Markowitz, H. (1952). Portfolio Selection. *The Journal of Finance 7*(1), 77–91.

Martin, J. G. and F. R. Westie (1959). The tolerant personality. *American Sociological Review 24*, 521–528.

Masolo, R. M. and F. Monti (2021). Ambiguity, Monetary Policy and Trend inflation. *Journal of the European Economic Association 19*, 839–871.

Muthukrishnan, A. V., L. Wathieu, and A. J. Xu (2009). Ambiguity aversion and the preference for established brands. *Management Science 55*, 1933–1941.

Norton, R. W. (1975). Measurement of Ambiguity Tolerance. *Journal of Personality Assessment 39*, 607–619.

Oechssler, J. and A. Roomets (2015). A test of mechanical ambiguity. *Journal of Economic Behavior & Organization 119*, 153–162.

Palma, A., M. Abdellaoui, G. Attanasi, M. Ben-Akiva, I. Erev, H. Fehr-Duda, D. Fok, C. R. Fox, R. Hertwig, N. Picard, P. P. Wakker, J. L. Walker, and M. Weber (2018). Beware of Black Swans: Taking stock of the description–experience gap in decision under uncertainty. *Marketing Letters: A Journal of Research in Marketing 3*, 269–280.

Poudel, R., M. C. Riedel, T. Salo, J. S. Flannery, L. D. Hill-Bowen, S. B. Eickhoff, A. R. Laird, and M. T. Sutherland (2020). Common and distinct brain activity associated with risky and ambiguous decision-making. *Drug and Alcohol Dependence 209*, 107884.

Qiu, J. and U. Weitzel (2012). Reference Dependence and Loss Aversion in Probabilities: Theory and Experiment of Ambiguity Attitudes. Working paper.

Quiggin, J. (2007). Ambiguity and the value of information: An almost-objective events analysis. *Economic Theory 30*, 409–414.

Ramsey, F. P. (1926). Truth and Probability. In R. B. Braithwaite (Ed.), *The Foundations of Mathematics and other Logical Essays*, pp. 156–198. London: Kegan, Paul, Trench, Trubner & Co., New York: Harcourt, Brace and Company. 1999 electronic edition.

Romain, A., M.-H. Broihanne, A. D. Marco, B. Ngoubangoye, J. Call, N. Rebout, and V. Dufour (2021). Non-human primates use combined rules when deciding under ambiguity. *Philosophical Transactions of the Royal Society B: Biological Sciences 376*(1819).

Rosen, N. O., E. Ivanova, and B. Knäuper (2014). Differentiating intolerance of uncertainty from three related but distinct constructs. *Anxiety, Stress and Coping 27*, 55–73.

Ross, N., P. Santos, and T. Capon (2012, 8). Risk, ambiguity and the adoption of new technologies: experimental evidence from a developing economy. In *International Association of Agricultural Economists (IAAE) 2012 Conference*.

Rotter, N. G. and A. N. O'Connell (1982). The relationships among sex-role orientation, cognitive complexity, and tolerance for ambiguity. *Sex Roles 8*, 1209–1220.

Rucker, P., J. Dawsey, Y. Abutaleb, R. Costa, and L. H. Sun (2020, 5). 34 days of pandemic: Inside Trump's desperate attempts to reopen America. *The Washington Post*.

Rydell, S. T. and E. Rosen (1966). Measurement and some correlates of need-cognition. *Psychological Reports 19*, 139–165.

Savage, L. J. (1954). *Foundations of statistics*. London: John Wiley & Sons, Inc.

Schmeidler, D. (1989). Subjective Probability and Expected Utility without Additivity. *Econometrica 57*, 571–587.

Schröder, D. and G. G. Freedman (2020). Decision making under uncertainty: the relation between economic preferences and psychological personality traits. *Theory and Decision 89*, 61–83.

Shaffer, D. R. and C. Hendrick (1974). Dogmatism and tolerance for ambiguity as determinants of differential reactions to cognitive inconsistency. *Journal of Personality and Social Psychology 29*, 601–608.

Shavit, H. (1975). Personality adjustment as a function of interaction between locus of evaluation and tolerance of ambiguity. *Psychological Reports 37*, 1204–1206.

Sheplse, K. A. (1972). The Strategy Of Ambiguity: Uncertainty And Electoral Competition. *American Political Science Review 66*, 555–568.

Sidanius, J. (1978). Intolerance of ambiguity and sociopolitico ideology: A multidimensional analysis. *European Journal of Social Psychology 8*, 215–235.

Slovic, P. (2010). *The Feeling of Risk: New perspectives on Risk Perception*. London: Routledge.

Slovic, P. and A. Tversky (1974). Who accepts Savage's axiom? *Behavioral Science 19*(6), 368–373.

Smithson, M. (1989). *Ignorance and Uncertainty*. New York: Springer.

Smithson, M. (1999). Conflict aversion: Preference for ambiguity vs conflict in sources and evidence. *Organizational Behavior and Human Decision Processes 79*(3), 179–198.

Sorrentino, R. M. and J.-A. C. Short (1986). Uncertainty orientation, motivation, and cognition. In R. M. Sorrentino and E. T. Higgins (Eds.), *Handbook of motivation and cognition: Foundations of social behavior*, pp. 379–403. New York, NY: Guilford Press.

Sutter, M., M. G. Kocher, D. Glätzle-Rützler, and S. T. Trautmann (2013). Impatience and Uncertainty: Experimental Decisions Predict Adolescents' Field Behavior. *American Economic Review 103*, 510–531.

Tanaka, Y., J. Fujino, T. Ideno, S. Okubo, K. Takemura, J. Miyata, R. Kawada, S. Fujimoto, M. Kubota, A. Sasamoto, K. Hirose, H. Takeuchi, H. Fukuyama, T. Murai, and H. Takahashi (2015). Are ambiguity aversion and ambiguity intolerance identical? A neuroeconomics investigation. *Frontiers in Psychology 6*.

Teitelbaum, J. C. (2007). A Unilateral Accident Model under Ambiguity. *Journal of Legal Studies 36*, 431–477.

Trautmann, S. T. and G. van de Kuilen (2015). Ambiguity Attitudes. In G. Keren and G. Wu (Eds.), *The Wiley Blackwell Handbook of Judgment and Decision Making*, Chapter 3, pp. 89–116. John Wiley & Sons, Ltd.

Trautmann, S. T., F. M. Vieider, and P. P. Wakker (2008). Causes of ambiguity aversion: Known versus unknown preferences. *Journal of Risk and Uncertainty 36*, 225–243.

Tversky, A. and D. Kahneman (1992). Advances in prospect theory: Cumulative representation of uncertainty. *Journal of Risk and Uncertainty 5*, 297–323.

van Den Bos, W. and R. Hertwig (2017). Adolescents display distinctive tolerance to ambiguity and to uncertainty during risky decision making. *Scientific Reports 7*.

Wakker, P. P. (2010). *Prospect Theory: For Risk and Ambiguity*. Cambridge: Cambridge University Press.

Webster, D. M. and A. W. Kruglanski (1994). Individual Differences in Need for Cognitive Closure. *Journal of Personality and Social Psychology 67*, 1049–1062.

Zuckerman, M. (1983). The distinction between trait and state scales is not arbitrary: Comment on Allen and Potkay's "On the arbitrary distinction between traits and states". *Journal of Personality and Social Psychology 44*, 1083–1086.