

## REVIEW

# How do we and how should we deal with uncertainty in endodontics?

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**Abstract**

In many clinical cases a dentist may feel certain when for example diagnosing, deciding on treatment, or assessing the prognosis—in other cases many dentists may feel a degree of doubt or uncertainty. This paper aims to explore the philosophical concept of uncertainty and its different dimensions, using the condition “persistent apical periodontitis associated with a previously root filled tooth” as an example. Acknowledging that uncertainty exists in any clinical situation can be perceived as uncomfortable, as some might regard it as a weakness. Whilst some types of uncertainty met in dental practice can be addressed and reduced, there are other types which are inevitable and must be accepted. To make sound decisions, it is pertinent that the dentist reflects on and values the consequences of uncertainty. In this paper, a conceptual model is presented by which the dentist can identify the type of uncertainty in a clinical case, making it possible to decide on a strategy on how to manage the uncertainty and its possible consequences, with the aim to support the dentist's care for their patients. The understanding that uncertainty exists and the ability to acknowledge and be comfortable with it when making decisions should be addressed throughout our professional career, and thus ought to be developed during undergraduate education. Some suggestions on how teachers could target this are given in the paper.

**KEYWORDS**

[clinical] decision making, endodontics, patient preference, periapical periodontitis, philosophy, uncertainty

**INTRODUCTION**

Assessment of a previously root filled tooth with apical periodontitis can be straightforward; if the patient is experiencing symptoms both the patient and the clinician are

probably fairly certain that there is an infectious condition that requires treatment. But how certain is the clinician when assessing and proposing actions regarding a previously root filled tooth with persistent apical rarefaction when the patient has no symptoms? The patient is probably

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unaware of the condition until the clinician informs about the findings from the radiograph and may question whether an additional intervention is indicated. Even though the European Society of Endodontology (ESE, 2006) states that follow-ups should be performed, dentists admit that these are often neglected (Malmberg et al., 2020; Markvart et al., 2018). Is this due to the high probability of finding periapical healthy conditions? Or does it perhaps reflect uncertainty as to whether the possible finding of persistent apical periodontitis would lead to a further intervention?

The classical work by Strindberg (1956) has been the foundation for academia when students learn how to assess and act on persistent apical periodontitis associated with a root filled tooth and forms the basis for the recommendations from the European Society of Endodontology (ESE, 2006). In summary, the paper proposed that apical periodontitis that persists after 4 years should be seen as an unfavourable outcome and require further treatment. However, from various studies it is obvious that clinicians do not follow these recommendations strictly, or perhaps not at all; for example, a systematic review reported that 41% of root filled teeth had apical periodontitis (Jakovljevic et al., 2020). Yet, few retreatments of root fillings are performed by general dentists (Fransson et al., 2016; Petersson et al., 2016; Wigsten et al., 2019).

In other words, there seems to be a dissonance between practice and beliefs regarding apical periodontitis associated with a previously root filled tooth. In this review, it can be argued that this dissonance could be at least partly explained by various types of uncertainty. Hence, this paper will present a philosophical discussion on uncertainty and provide examples related to persistent apical periodontitis associated with root filled teeth. This clinical scenario should be seen as just one example within endodontics of a situation where uncertainty may be present, but a decision on patient management must be made, nevertheless. Other examples may be assessment of the severity of pulp inflammation (i.e., is it possible or not possible to reverse pulp inflammation by using conservative pulp treatment) or assessment of prognosis for a tooth displaying a visible crack or root resorption, etc. Strategies to manage uncertainty in endodontics and how dealing with uncertainty could have implications for education will also be proposed.

## REVIEW

### What is uncertainty?

Uncertainty is present when we do not know. This can be because we simply have less information than we need or it can be because we are fully informed about a process in the world that is inherently uncertain. This reveals

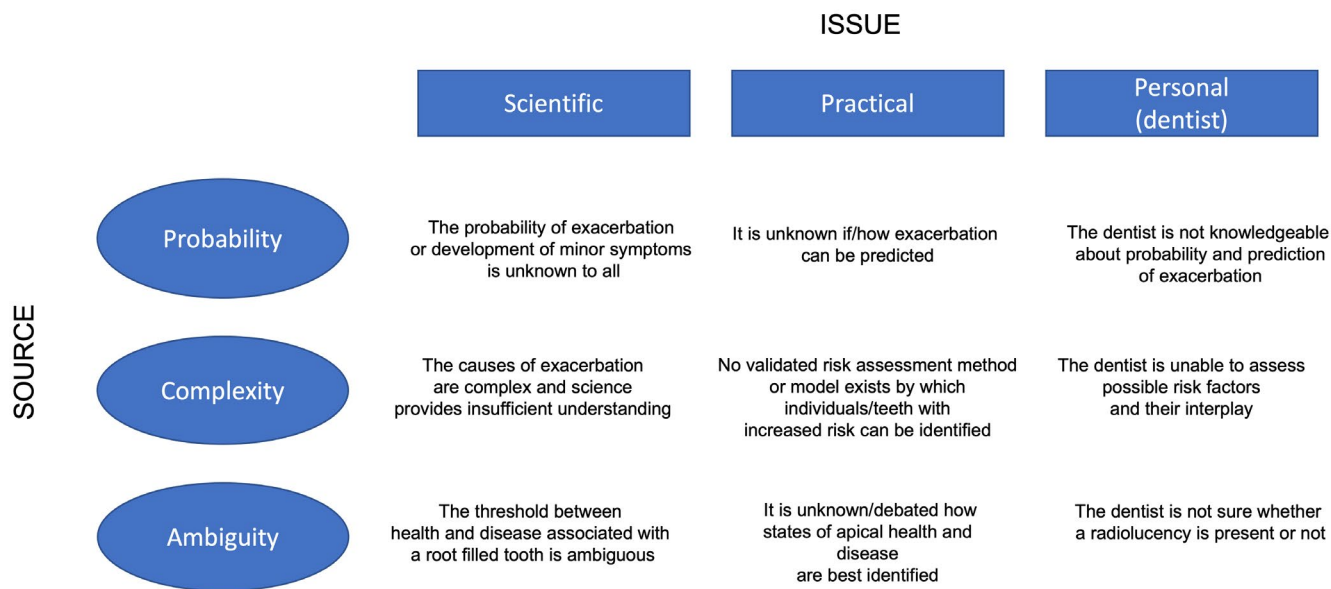
two different sources of uncertainty: the epistemic state of the individual and the state of the world. The difference is conveyed through the use of language: that *I am uncertain* whether the radiograph shows a tooth with apical periodontitis is an example of the first kind of uncertainty versus if I claim that *it is uncertain* whether what is seen on the radiograph represents apical periodontitis (disease) or not suggests the second kind of uncertainty. The former has been variably termed *incertitude* or *internal/epistemic uncertainty* and the latter *natural variability* or *external/aleatory uncertainty* (Juanchich et al., 2017). Whether these are synonyms or if they are distinct concepts is debatable (Fox & Ülkümen, 2011). What they all want to capture, in their possibly somewhat different ways, is that some dimensions of uncertainty exist as features of the external world that we must accept (the aleatory/external/variability type), but also that some dimensions of uncertainty are due to our limited knowledge (the epistemic/internal/incertitude type) that can be reduced by improving our epistemic situation; that is our understanding. Both can ideally be expressed quantitatively through probabilities, or, when epistemic uncertainty is significant, with probability intervals (Kyburg, 1974) or qualitative expressions to that effect (Mach et al., 2017; Moss & Schneider, 2000). The types of uncertainty discussed in this paper are explained in Table 1, and general examples are provided.

Uncertainty matters perhaps most when we are about to make decisions. In the choice between action alternatives, we need to know in what state the world might be and what the consequences will be if an act is performed given a certain state of the world. Uncertainty regarding what state will exist can be external, if random processes are at work, but of course also internal. What the consequences will be can also be uncertain due to features of the world and in addition, by what we presently know, or can imagine, about what may follow on a certain action.

There are many different definitions of uncertainty, and several different suggestions of a taxonomy of uncertainty. Many are discussed in a review by Han et al. (2011), in which also a taxonomy for uncertainty in health care is presented. The basic concept of Han et al. (2011), and one that is borrowed from Smithson (1989), is that uncertainty has a *source* and an *issue*, that is, what gives rise to it and to what it applies, respectively. The sources are “probability”: events that are indeterminate, “ambiguity”: information of the event is unreliable or inadequate, and “complexity”: difficulties in structuring the decision problem for example due to a multitude of possible outcomes of a treatment. The issues are “scientific”: diagnosis, prognosis, causal explanations, treatment recommendations; “practical”: structures of care, processes of care; and “personal”: psycho-social, existential (Han et al., 2011). To put

**TABLE 1** Terms related to various types of uncertainty discussed in this paper, with explanations and examples

| Term  | Explanation   | Example  |
|---|---|--|
| Internal uncertainty ( <i>incertitude</i> )         | Uncertainty pertaining to the knowledge of the individual         | I am uncertain <i>if/how/when/what/which</i> etc                         |
| External uncertainty                                | Uncertainty pertaining to the state of the external world         | It is uncertain <i>if/how/when/what/which</i> etc                        |
| Epistemic uncertainty                               | Systematic uncertainty  | X is unknown in practice (but could on principle be known)               |
| Aleatory uncertainty ( <i>natural variability</i> ) | Statistical or random uncertainty                                 | X is unknown because it varies in a random (or extremely complex) manner |
| Ambiguity   | Inexact, undefined, or possible to interpret in more than one way | X depends on what is meant by Y  |



**FIGURE 1** Various types of uncertainty exemplified in the case of a root filled tooth with persistent apical periodontitis. Identifying the *source* and the *issue* of uncertainty in a specific case will clarify the nature of uncertainty and be helpful to guide how it might be managed. (Figure based on Han et al., 2011)

it in general terms, the issues to which uncertainty apply comprise anything that has a bearing on decision making: what alternative actions there are, what state the world might be in at the time action is taken, what the consequences of the acts, given a certain state of the world, might be, and how to value these consequences. The locus can be the physician or the patient, or both (Han et al., 2011), that is, the physician can entertain uncertainty and so can the patient.

As is clear from the choice of issues, Han et al. (2011) aimed at identifying types of uncertainty in the full context of treatment, from scientific statements about diagnosis and effective treatment alternatives, through the ability of the system to provide the treatment, to the patients’ view on how an illness and possible treatment will affect their life.

In the following, the basic structure from Han et al. (2011) will be used but the focus will be more narrowly

on the scientific issues, from the practitioner’s perspective. Figure 1 exemplifies the conceptual model by identifying uncertainty regarding the diagnosis of root filled teeth with persistent apical periodontitis. The issues in Figure 1 are not about the areas of science, organization, person, as they are in Han et al. (2011). Instead, they are all in the area of science, where “scientific” is about scientific knowledge about the phenomenon, “practical” refers to uncertainty regarding methods for prediction, assessing risk, or for identifying states, and “personal” is the epistemic uncertainty, lack of training, etc. of the individual practitioner.

The sources are first “probability”, or perhaps knowledge, which indicates that there is a lack of information, or knowledge, on which to base a reliable judgement. Second, there is “complexity”. The causes of a negative event can be many and intertwined, and the scientific understanding is inadequate, but complexity can also lead

to unreliable risk assessment models and to a practitioner being insecure about what risk factors to focus on in the discussion with the individual patient. Lastly, “ambiguity” encompasses a source of uncertainty that is not clearly present in Han et al. (2011), that is, linguistic uncertainty. With poorly defined scientific concepts follows a lack of precision in the diagnosis and the possibility of disagreement between practitioners based not on facts but on a different understanding of vague or ambiguous terms. The source of ambiguity can also be conflicting information on which it is difficult for the practitioner to base a decision.

### **What are the implications of uncertainty for the practitioner?**

Uncertainty is well known in medical practice, and the same is true for dentistry. As discussed above and proposed in Figure 1, the clinical situation involves uncertainty in many ways. Why does this matter, and how does it affect the dentist? No publications address this issue, but in emergency medicine, it has been suggested that intolerance of uncertainty and ambiguity, particularly regarding outcome of treatment, is associated with practitioner anxiety and burnout, and reluctance to admit uncertainty and mistakes to patients and other practitioners, which suggests suboptimal communication (Kuhn et al., 2009). In general medical practice, low tolerance for ambiguity has also been associated with a biomedical rather than a biopsychosocial worldview of the practitioner, and failure to comply with evidence-based guidelines (Geller, 2013). In contrast, high tolerance for ambiguity in dual-degree students (Doctor of Medicine and Master of Business Administration) was associated with superior leadership abilities (Sherrill, 2001). It thus appears likely to be beneficial for the dentist—and endodontist—both as practitioner and as practice leader to recognize, understand, and tolerate uncertainty.

### **Possible strategies to manage uncertainty when encountering a root filled tooth with persistent apical periodontitis**

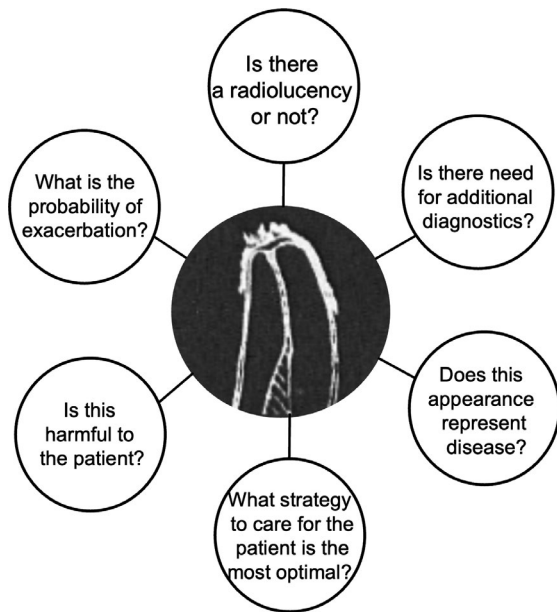
#### **Acknowledging uncertainty and identifying what the issue is**

To be able to handle clinical uncertainty in a conscious way, dentists first need to acknowledge that uncertainty exists. This may be more challenging than it sounds. The present paradigm by which we understand the world leans heavily towards positivism (in which reality is defined in terms of scientifically proven facts and logical principles) and away from humanism (in which human experience

and rational thinking are necessary means to understand reality). This paradigm tends to encourage operationalized, simplified management strategies and discourage reflection, pluralism, and acceptance of variations. As a result, a culture of certainty prevails within many professions, dentistry included (von Bergmann & Shuler, 2019). Yet, a review examining a variety of healthcare settings concluded that professional uncertainty in scientific, practical, and personal domains as described by Han et al. (2011) exists throughout healthcare disciplines (Pomare et al., 2019). The emergence of systematic literature reviews in recent years may actually have alerted dentists and other healthcare professionals to the presence of uncertainty by revealing the lack of evidence for the validity or efficacy of various procedures. Still, acknowledging feelings of uncertainty may feel uncomfortable and the dentist may feel that it even threatens their professional credibility. To increase comfort with feelings of uncertainty, it may be helpful to first identify the issue to which the uncertainty applies, for example, if the uncertainty exists in the domain of diagnosis, prognosis, causal explanations, or appropriate treatment choice (Han et al., 2011). Figure 2 shows a case of (possible) apical periodontitis associated with a root filled tooth and exemplifies how uncertainty in a specific clinical case may well exist in several or all of those domains.

#### **The sources of uncertainty—can they be addressed, and how?**

When dentists have acknowledged the existing uncertainty in managing root filled teeth with persisting apical periodontitis, the search for the *source* of uncertainty can begin. Seeing the difference between various origins of uncertainty can be challenging, especially for a clinician in their early career (Fox, 1957). Various strategies can be adopted depending on the source of the uncertainty. When the uncertainty is external/aleatory, stemming from complexity, a tempting solution could be to add more information for example by using additional diagnostic tools, such as cone beam computed tomography (CBCT). But the problem is that adding more diagnostic methods does not always overcome the uncertainty, that is, one test often leads to more tests, adding more diagnostic uncertainty (Jha, 2014). In the case with CBCT, it has been reported that the method is less accurate for detecting periapical bone destruction associated with root filled teeth, with lower sensitivity as well as specificity compared to when it is applied to untreated teeth (Kruse et al., 2019). The low positive predictive value (0.48–0.65) suggests that the presence of apical periodontitis in root filled teeth may



**FIGURE 2** Uncertainty may exist in several domains. This drawing of a root filled tooth and its radiographic appearance illustrates a clinical case but is merely used as an example—the periapical appearance could be more, or less, pronounced. The patient experiences no symptoms. To one dentist, no feelings of uncertainty are evoked when asked how to manage the tooth. Regarding the exact same case, another dentist may feel uncertain and be comfortable with acknowledging it. A few examples of different dimensions of their uncertainty are suggested. (Drawing borrowed from Ørstavik et al., 1986, with permission)

be systematically overestimated when CBCT is used (Kruse et al., 2019). CBCT has also been suggested to overestimate the frequency of post-treatment disease (Christiansen et al., 2009). Worth noting is that in comparison, the positive predictive value of intraoral periapical radiography is actually reported to be somewhat higher (0.67–0.75), although data specifically on root filled teeth is lacking (Brynolf, 1970; SBU, 2010). This emphasizes the need to consider carefully whether an available additional diagnostic measure has potential to decrease uncertainty, or whether it may increase it. In addition, low level of tolerance for uncertainty in medical primary care has been associated with higher costs for care due to increased and unnecessary investigations being undertaken (Allison et al., 1998). Instead, a useful strategy may be to critically assess the underlying assumptions that we use when we think about various consequences to allow a strategy to take informed action to be developed. As a scaffold or framework, it may be useful to think in terms of benefits, costs, and risks of different paths of action.

One internal/epistemic source of uncertainty could be the limitations in the clinician's own knowledge. If the dentist does not know how to interpret a radiograph or

is inexperienced in endodontic diagnostics, the solution could be additional training, for example, to reflect on the subject with a colleague. This takes time and studies have found that time is crucial for clinicians to engage in reflection (Jonas-Dwyer et al., 2013; Nasseripour et al., 2021). To facilitate the ability for clinicians to deal with uncertainty not only as novices but throughout their careers, the structures around them, for instance their employers, need to support them (Wooster & Maniate, 2019).

Another internal/epistemic source of uncertainty is the recognition that the available information is incomplete. Information can be incomplete because full information is simply not available, that is, knowledge is lacking. In endodontics, it is well established that there is insufficient scientific evidence supported by quality data in many areas, including diagnostics regarding periapical status in general and particularly in relation to root filled teeth (Bergenholtz & Kvist, 2013; Duncan et al., 2016; Pigg et al., 2021; SBU, 2010). But information can also be incomplete because the clinician is not fully informed of the knowledge that is actually available. Despite, or perhaps due to, the rapid advances in science and constant changes in the standard of care, sources of uncertainty will always remain to some degree; in other words, it is increasingly difficult for the individual to keep up with developments in terms of new knowledge, skills, equipment, and procedures (Wooster & Maniate, 2019). By becoming specialized in a field, for example, Endodontology, the range of potential uncertainty that one has to deal with in clinical practice is reduced (Fox, 1957).

### Consequences of uncertainty and how to value them

So how should one think when assessing the risk for exacerbation to occur from a root filled tooth with persistent apical periodontitis—and what measures should one take given a balanced attitude towards uncertainty? The position of extreme caution would be to extract all root filled teeth with persistent apical periodontitis and thereby eliminating any risk of future consequences caused by infection from these teeth. This was popular in the era of the “focal infection theory”, in the beginning of the 20th century when Endodontology was almost removed from the dental curricula (Gulabivala et al., 2014). Less extreme but still action-focused approaches have been suggested; in his classical work, Strindberg (1956) proposed a system where he recommended deciding on retreatment or extraction upon diagnosing a new or a persistent periapical lesion. In the 1980s, Reit and Gröndahl (1984) recognized the possibility of

inaction by proposing a decision tree with the alternatives *no treatment*, *wait and see*, *extraction*, *surgical retreatment*, and *nonsurgical retreatment*. Subsequently, Kvist (2001) suggested adding subjective values to the decision process by adding the principles: respect for patient autonomy, treatment risks, and the monetary costs for retreatment.

Perhaps a reasonable goal is to find a middle ground, balancing between on the one hand the probability of an exacerbation of apical periodontitis occurring and the accompanying risk for consequences of varying nature and severity such as pain, local or systemic spread of infection, and tooth loss, and on the other hand the economic issues associated with endodontic treatment or need of replacement of an extracted tooth. The probability of experiencing an exacerbation and the risk of serious consequences will vary from case to case and information from clinical studies about the factors predicting exacerbation are lacking. The possible paths of action alternatives include additional diagnostics, watchful waiting, orthograde or retrograde retreatment, and extraction. Serious consequences could include different scenarios from life-threatening spread of infection to an impaired quality of life caused by the loss of an anterior tooth. If the probability for exacerbation is very low but the consequences if it occurs are severe, such as in a patient with intravenous bisphosphonate treatment, or with a history of radiation in the orofacial region, one might decide on treatment to further reduce the risk. In contrast, in a systemically healthy patient for which no events that would merit a more vigilant attitude are anticipated and with the same probability of an exacerbation, it may be more reasonable to adopt the watchful waiting approach. The patient must have the final say in the decision after being informed about the risk of consequences and the risks involved in treatment as well as in no treatment and about the overall uncertainty. One can assume that the patient's own feelings of comfort or discomfort with uncertainty will influence the decision to treat or not to treat and the choice of treatment alternative.

### **When and how do dentists learn to manage uncertainty? Implications for education**

What, then, can be done to increase dentists' awareness of uncertainty, improve their management of it, and reduce their feelings of discomfort with the situation? How, and when, do dentists acquire their approach to situations with inherent uncertainty? Concern has been raised that the culture of certainty in the dental profession starts during undergraduate education (von Bergmann & Shuler, 2019). The implications are interesting from several perspectives. As previously mentioned, intolerance to

uncertainty is associated with increased rates of anxiety (Kuhn et al., 2009), a state that in turn correlates with reduced academic achievement in students (Pekrun et al., 2002). Thus, early training of students in the health professions to accept and manage the inevitable issues of ambiguity might improve their academic performance as well as prepare them for their future clinical practice (White & Williams, 2017). Strategies for managing uncertainty in clinical practice can vary depending on how the clinical instructors acted during the clinical education. Clinicians trained in an environment where uncertainty is considered a problem that needs to be overcome tend to adopt the same manner of thinking about uncertainty (Bochatay & Bajwa, 2020) and are prone to display a manner of certainty even when they do not actually feel certain. To avoid this development and instead strive to instil comfort with being uncertain, teachers can openly acknowledge their own perceptions of uncertainty and show that they are willing to reflect together with students. At first, it may be challenging and difficult for both students and teachers to reveal feelings of uncertainty but examining the sources and issues of uncertainty can potentially deepen students understanding of the subject and be helpful in their professional life. As with other applications of critical thinking, targeted exercises can be designed to make reflection a part of every clinical session (Botelho & Bhuyan, 2021; Kuhn, 1999; Lee & Ryan-Wenger, 1997).

One important issue when discussing how dentists learn to manage uncertainty in endodontics and in dentistry in general is that learning outcomes and curricula should reflect that knowledge about and ability to manage uncertainty are desired outcomes. Programmes should thus incorporate these competencies into course objectives, learning activities and assessment; all according to the principles of *constructive alignment* (Biggs & Tang, 2011). In the same way as students are encouraged to accept uncertainty as inevitable when teachers and instructors deal with uncertainty in a straightforward manner in front of them (Fox, 1957), experts in the field, for example, endodontists and endodontic researchers should act as role models by acknowledging uncertainty as an unavoidable component of a complex discipline and inspire dentists as a group to do the same.

### **CONCLUSIONS**

Uncertainty exists in many domains within medicine and dentistry, and endodontics is no exception. Using persistent apical periodontitis associated with a root filled tooth as an example, various types (or dimensions) of uncertainty have been discussed, as well as how identifying the source and issue of uncertainty in

different clinical cases may be helpful to the dentist by providing guidance on how the uncertainty may be managed, for example, indicating whether additional diagnostic procedures will be helpful or when improving one's personal knowledge is a possible remedy. Dentists' awareness and thought processes may be helped by open discussion about what we do not know, on different levels. Openness of discussion and reflection within our discipline and especially within dental education is likely helpful to improve dentists' comfort with decision-making and subsequent action when they are uncertain, but this remains to be tested in empirical studies involving students and clinical practitioners.

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### CONFLICT OF INTEREST

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### ETHICAL APPROVAL


This research did not require ethical review, since it is a theoretical discussion paper.

### AUTHOR CONTRIBUTIONS

The authors all contributed to the ideas and design of this research and to the drafting of the article.

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