

The Inconsistency between Theory and Practice in Managing Inconsistency in Requirements Engineering



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Vocabulary

- RE requirements engineering
- RS requirements specification
- CBS computer-based system,
that is under design, about which
RE is done to produce RS

Vocabulary

- IM inconsistency management
- VPF ViewPoints Framework
- ZJVF Zave–Jackson Validation Formula
- RQ research questions
- DA data analysis
- GA grounded analysis

Inconsistency in RE is defined as:

- “any situation in which [at least]* two parts of a requirements specification [for the CBS] do not obey some relationship that should hold between them.”

(Easterbrook and Nuseibeh 1996)

* context suggests amendments

Inconsistency in RE may occur in:

- conflicting or contradictory descriptions of the expected behavior of the system,
- conflicting goals between different stakeholders,
- changes introduced during the evolution of the requirements,
- incorrect assumptions made about the real world.

How should we handle inconsistencies?

Examples of practitioners' answers:

- *We must eliminate on sight.*
- *They must always be resolved. ASAP.*
- *They must be fixed.*
- *As soon as we find it, it needs to be investigated and solved.*

RE Community's View of Inconsistency

- Inconsistency in RE has been in the RE community's spotlight since the early 1990s.
- The early literature on inconsistency in RE considered inconsistency in an emerging RS to be a problem that needs to be eliminated on sight.

How should we handle inconsistencies?

Examples from literature:

- “Inconsistent systems are an ‘**epistemic hell**’
to be avoided at all costs”
(Gärdenfors, P., and Makinson, 1994)
- “Inconsistency [in SE] is viewed as undesirable,
to be avoided if at all possible”
(Nuseibeh et al., 2001)



How should we handle inconsistencies?

In early 2000s, the RE Community began to recognize that maintaining consistency at all times is

- not only infeasible
(sometimes, just don't know enough about CBS to resolve inconsistency),
- but also even counterproductive
(might freeze to early decision that proves later to be wrong),

and therefore:

Managing inconsistency in RE

“Maintaining consistency at all times is counterproductive. In many cases, it may be desirable to **tolerate** or even **encourage inconsistency** to facilitate distributed teamwork and prevent premature commitment to design decisions.”

(Nuseibeh et al., 2001)

Paradigm shift

- “To turn inconsistency into a tool, inconsistency management must become central to your development process.”
(Nuseibeh et al., 2000)
- Managing inconsistency “requires a major change in the way we think.”
(Finkelstein, 2000)



Key elements of IM

Key element of IM: *Tolerating inconsistency*

- *temporarily*, during analysis until understand the CBS enough to resolve inconsistency correctly, or
- *permanently*, when part of the requirements specification (RS) is simply not true about the world, albeit rarely or with little impact.

Document each toleration; so don't forget!

RE Community and IM

The RE Community

proposed, developed, and applied in case studies paradigms and tools for IM.

We use one such paradigm, the *ViewPoints Framework (VPF)* as a representative of a lot of similar paradigms.

Inconsistency management in theory: **The ViewPoints Framework**

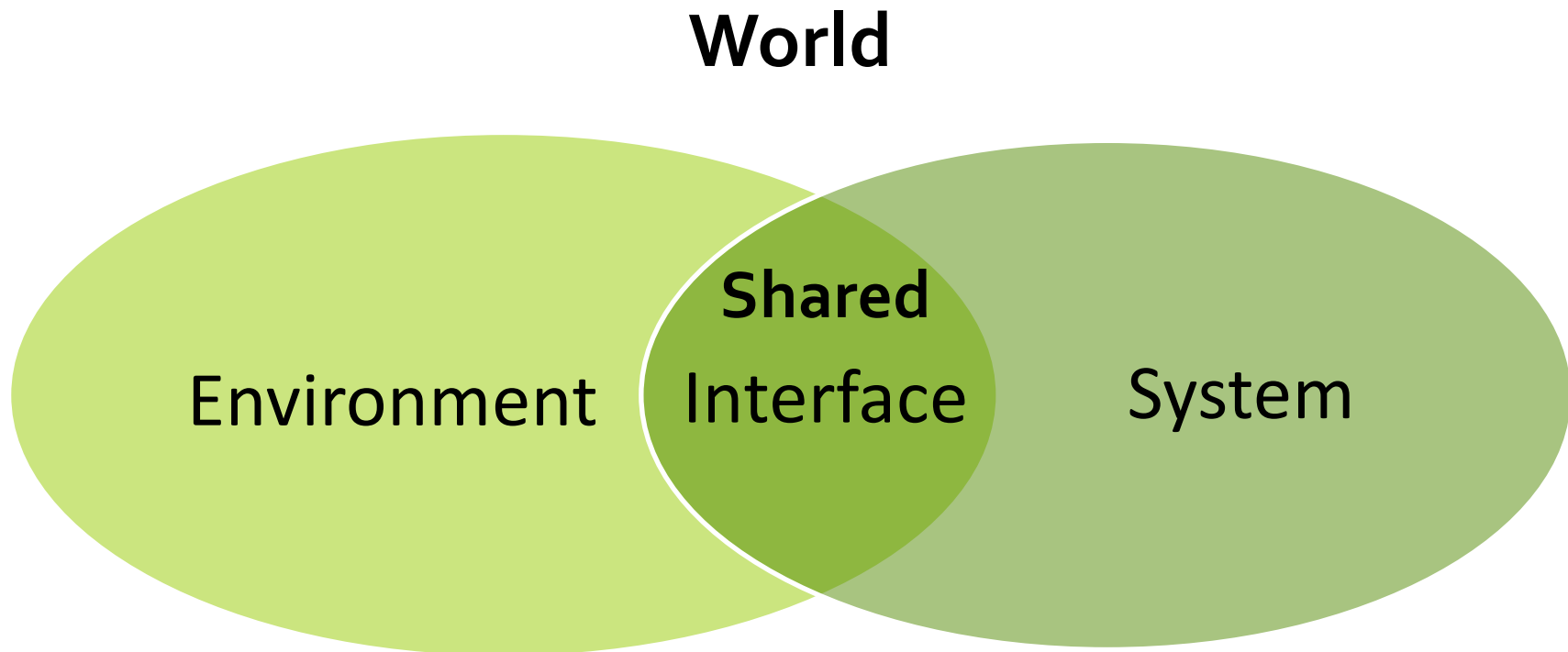
Different kinds of mitigations:

- Resolving
- Ignoring
- Deferring
- Ameliorating
- Circumventing

IM in practice: VPF

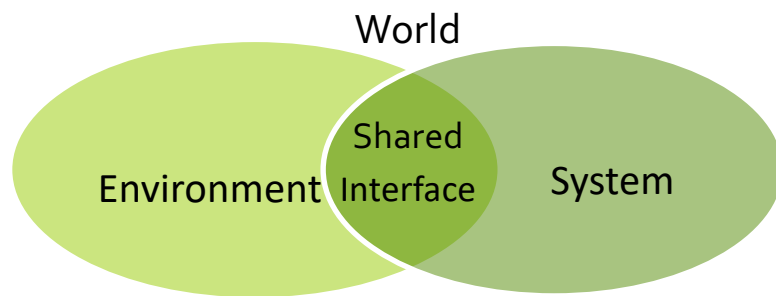
- Because of vagueness of mitigations and difficulty distinguishing between them, Berry never considered VPF or any similar paradigm to be very operational.
- After learning the RE Reference Model and Zave–Jackson Validation Formula (ZJVF), he started using it for IM.

Inconsistency management in theory: The Zave–Jackson Validation Formula



$D, S \vdash R$ (D & S residing in Env, and S in Intf)

Inconsistency management in theory: The Zave–Jackson Validation Formula



$$D, S \vdash R$$

(all residing in Env, and Sys in Intf)

Inconsistency manifested as

- logical failure to prove entailment ($\vdash$) or
- empirical failure to match realities in the Environment

Tolerating Inconsistency in ZJVF

Tolerating inconsistency in the ZJVF:

- *temporarily*, during analysis until understand the CBS enough to be able to prove corrected entailment $D, S \vdash R$, or
- *permanently*, when part of D is simply not true about the world, albeit rarely or with little impact, and we decide to pretend that it is true, because it's impossible for S to do anything about it*.

Document each toleration; so don't forget!

* e.g., we pretend that “all drivers obey red lights”, to accept that a traffic light prevents perpendicular collisions, because a traffic light currently cannot do anything about it.

Preliminary study and onwards

- In the meantime, over the same period, how developers perceive and manage inconsistency in practice had not received much attention.
- A 2015 Study by Hadar & Zamansky showed that practitioners considered inconsistency in an emerging RS to be a problem that needs to be eliminated on sight.

Preliminary study and onwards

- Berry saw this work, and showed them the ZJVF and how he managed inconsistency.
- H & Z had not seen any sign of ZJVF or of the thinking it supports in their study.
- So H, Z, & B decided to work together to study practitioners' perceptions about IM in greater depth.
- They formulated the following RQs:

Research questions

- **RQ1** What are the manifestations of inconsistency in RE practice, as perceived by practitioners?
- **RQ2** What are the attitudes of practitioners toward these manifestations?

Research questions, cont'd

- **RQ3** What strategies do practitioners think should be applied to address these inconsistency manifestations?
- **RQ4** More specifically, what are the perceptions and attitudes of practitioners with regard to inconsistency toleration as a solution strategy?

The empirical study

Qualitative Study

- 51 participants
 - IS or CS background
 - professional experience in RE
- Data collection:
 - In-depth interviews (24 interviewees)
 - Open-ended questionnaire (27 respondents)



The empirical study

This study aimed to better understand

- the phenomenon of inconsistency and
- the strategies to address it in RE practice.

The study investigated

- experienced practitioners' perceptions of inconsistency manifestations in RE,
- their attitudes towards these manifestations, and
- strategies they apply to address inconsistency in real-life software development projects.

Data Analysis with Grounded Analysis

Data analysis was guided by the principles of GA and interpretive research.

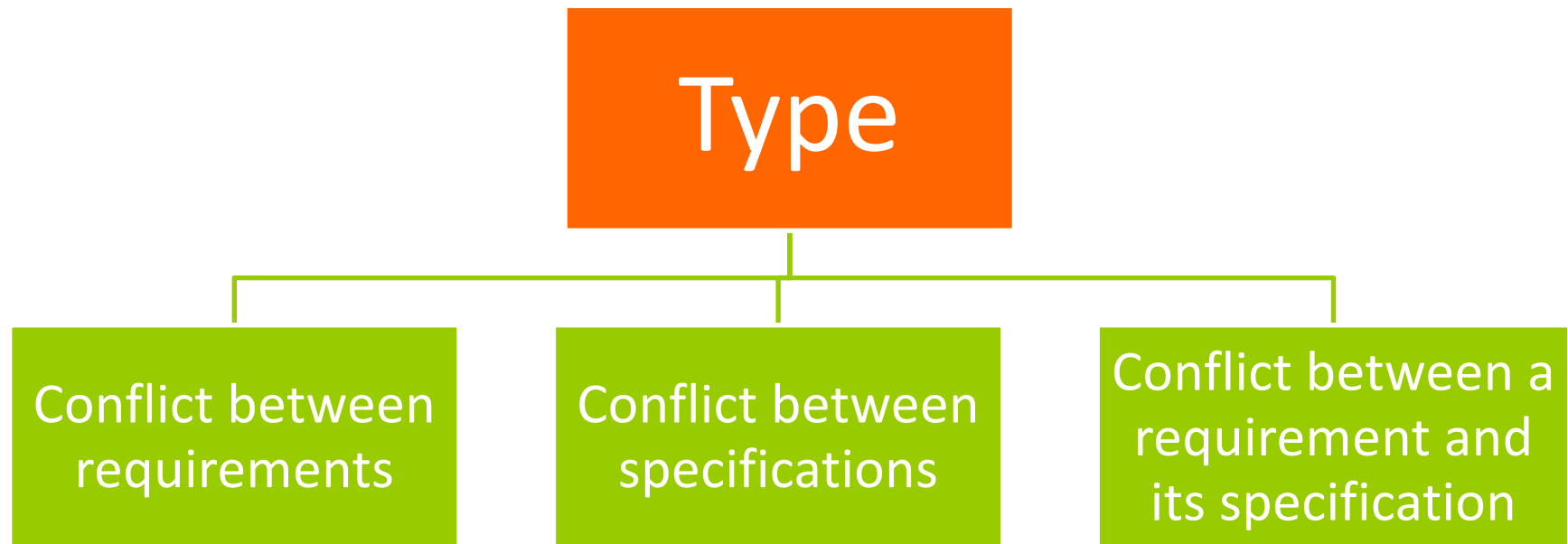
GA of the data led to

- the emergence of categories that
- closely match the two IM paradigms
 - VPF
 - ZJVF
- However, the match between theory and practice is not perfect.

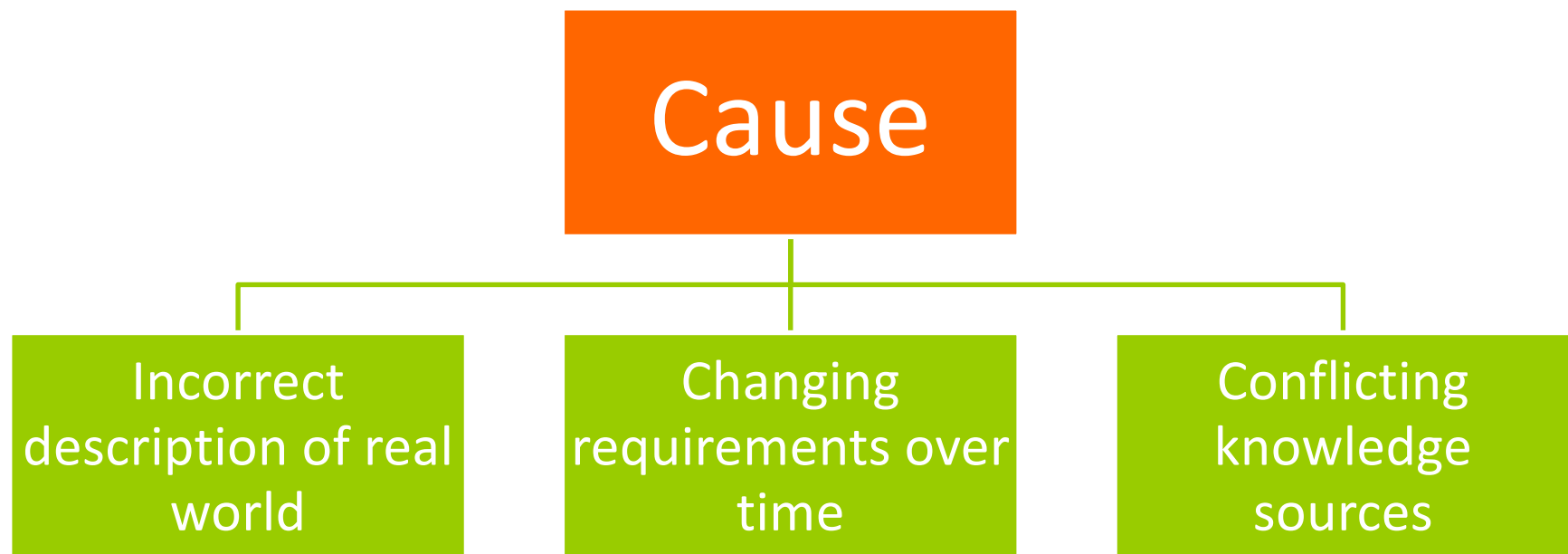
Findings



Perceptions of inconsistency in RE (1)



Perceptions of inconsistency in RE (2)



Perceptions of inconsistency in RE (3)

Cause \ Type	Conflict between requirements	Conflict between specifications	Conflict between a requirement and its specification
Incorrect description of real world	v	v	v
Changing requirements over time		v	
Conflicting knowledge sources		v	v

Perceptions of inconsistency in RE (3)

	Type	Conflict between requirements	Conflict between specifications	Conflict between a requirement and its specification
Cause				
Incorrect description of real world		V	V	V
Changing requirements over time			V	
Conflicting knowledge sources			V	V

“v” in a cell says only that there was *an indication* among the participants of a causal relationship between the cell’s cause and type.

Lack of “v” in a cell means *only* that there was *no indication* among the participants of a causal relationship between the cell’s cause and type; it does not mean that there is no such causal relationship.

Attitudes toward inconsistency in RE

- *I dislike it very very much.*
- *I feel troubled.*
- *I feel disappointment, confusion, anger.*
- *Something obnoxious which takes time and energy.*
- *Bummer! I feel ashamed if I wrote that [inconsistent requirements]; if someone else wrote that, I feel sorry for them.*

Attitudes toward inconsistency in RE

- *I really don't like this, because it introduces uncertainty, and this bothers me personally*
- *Contradicting requirements pose a real problem, because the person who will implement the system, should know what should be done. How will you develop — according to this or that?*

Addressing inconsistencies

No toleration:

- *We must eliminate on sight. (M)*
- *It must be fixed. (L)*
- *Must always be resolved, ASAP. (L)*
- *If there are contradictory requirements, one should approach the individual who defined the requirements and demand a clarification. (L)*
- *One needs to go and ask the person who wrote the requirements which of them should be developed. Eventually, a decision has to be made. (L)*

Level of responsibility to fix inconsistency: **Low**, **Medium**, **High**

Addressing inconsistencies

Temporary toleration:

- *I wish to fix all of them [inconsistencies], but inconsistency related to user experience I would always prioritize higher. (H)*
- *If it is about inconsistent requirements, we can check the source of the requirements and see whether they can be rephrased so to be consistent. If it is not possible, then they need to be prioritized. (M)*
- *We need to prioritize what [inconsistency] to solve first. It is in the list of open issues. (M)*
- *Sometimes it's better to stay with the inconsistency until this information becomes available. (L)*

Addressing inconsistencies

Permanent toleration:

- *It is almost never possible to meet 100% of the requirements with no inconsistencies. I prefer to have some inconsistency if it means meeting more requirements. (H)*
- *It needs to be considered what is preferable. It might be possible to fix. Then you may achieve consistency, but at the same time you damage something else. Sometimes it's better to have inconsistencies in the program, but gain something else. For example, you may reduce running time by allowing the inconsistency. (L)*

Challenging their responses

*Imagine there is a case in which there is an **inconsistency** in requirements relevant only to rare cases,*

however –

***resolving** this situation would be of **high cost**.*

What would you do?

One response pattern

1. Immediate acceptance of the rationale of tolerating inconsistency, despite having rejected it until that point in the interview

In this case, the inconsistency may be tolerated. If it has no legal meaning, it's possible to leave it.

(Project manager, 17 years of experience)

One response pattern

1. Immediate acceptance of the rationale of tolerating inconsistency, despite having rejected it until that point in the interview

The fact that there are two contradictory requirements doesn't mean that they are important. Perhaps they refer to situations most users won't encounter, and then perhaps they do not even have to be fixed.

(Developer, 3 years of experience)

One response pattern

1. Immediate acceptance of the rationale of tolerating inconsistency, despite having rejected it until that point in the interview

I guess that in such situations one can consider leaving it as is, and of course document.

(Developer, 6 years of experience)

Second response pattern

2. Slow transitioning from strong rejection to reluctant acceptance.

*There is no such thing! It shows a severe failure.
[Pause] It's all about matching expectations. It's
about the contract between you and the customer.
(Chief architect, 20 years of experience)*

Second response pattern

2. Slow transitioning from strong rejection to reluctant acceptance.

I can't see how that's possible. There are no situations like this. If it's a primary issue, I don't see how it can be ignored regardless the cost. If it's something small, it may be possible. The final answer depends on the type of inconsistency.

(Senior architect, 16 years of experience)

Second response pattern

2. Slow transitioning from strong rejection to reluctant acceptance.

No one would ever agree to live with it. I, for sure, wouldn't be able to live with it. [Pause] It's all about cost verses benefit. If it's a minor problem, it would ignored.

(Senior developer, 10 years of experience)

Intuitions

Our results show that:

- Practitioners initially strongly reject the very idea of not immediately eliminating inconsistency.
- They often remain reluctant, even when they admit that this idea makes sense.

Possible explanation: the *dual-process theory*

The dual-process theory

Suggests that two separate systems operate within each person's mind (Kahneman , 2002):

System 1: Intuition	System 2: Reasoning
Fast	Slow
Parallel	Serial
Automatic	Controlled
Effortless	Effortful
Associative	Rule-governed
Slow-learning	Flexible

Preliminary results

- Our preliminary results show that:
 - Practitioners initially strongly reject the very idea of not immediately eliminating inconsistency
 - they often remain reluctant, even when they admit that this idea makes sense
- Possible explanation: the dual-process theory
 - **Intuition may hinder integrating new ideas, as reasonable as they may be, into our thinking processes.**

Analyzing the data through the lens of the dual-process theory

The attitude change can be explained as the intervention of S2, overriding the initial S1 response:

Inconsistency is an evil to be eliminated on sight.

Analyzing the data through the lens of the dual-process theory

Observed tension in one participant

It [the inconsistency] can be tolerated. I, personally, would fix it in any case, because things need to be consistent. Consistency is important for software.

Analyzing the data through the lens of the dual-process theory

Observed tension in the same participant

If I have a way to confirm, that this [the inconsistency] is indeed very esoteric, and that it would indeed cost a lot to fix it, then it may be tolerated. It's a decision of the higher management. But it seems to me very individual. I would for sure fix it. But it can be a strategic decision [to tolerate the inconsistency]. Ideally, clearly it should be fixed. In reality there are additional considerations, mainly economic ones.

The dual-process theory & IM

The dual-process theory applied to explain behavior in IM

- Seeking-out-and-eliminating-inconsistency is from a practitioner's System 1
- Tolerating-inconsistency-at-least-temporarily-and-possibly-permanently is from the practitioner's System 2.

The dual-process theory & IM

Kahneman observes that highly competent experts in a field

➤ that requires logical thinking

➤ in which an average person's intuitive thinking leads to trouble

have internalized the repeated logical thinking to the point that it has become intuitive,

i.e., the thinking has migrated from System 2 to System 1.

The dual-process theory & IM

Perhaps with enough practice, practitioners can come to accept and actively

use tolerating-inconsistency-at-least-temporarily-and-possibly-permanently as an effective strategy, i.e., to

routinely frame systems in a way that allows the ZJVF to be used to deal

with inconsistencies in a logical way.

Discussion: Revisiting the RQs

- **RQ1** What are the manifestations of inconsistency in RE practice, as perceived by practitioners?
 - Practice is well-modelled by theory:
 - There is a clear reflection of the types of inconsistency and their causes as described by the VPF and the ZJVF in the data we obtained from the practitioners.
 - The types of inconsistency that appear in the ZJVF are those of the manifestations of inconsistency in practice.

...

Discussion: Revisiting the RQs

- **RQ1** What are the manifestations of inconsistency in RE practice, as perceived by practitioners?
 - Practice is well-modelled by theory:...
 - The causes of these types of inconsistency are those appearing in the VPF.
 - Yet, not all ontological distinctions proposed by the theory are reflected in the practice:
 - Most notably, the concept of domain assumptions central to the ZJVF does not show up in our practitioners' discourse.

Discussion: Revisiting the RQs

- **RQ2** What are the attitudes of practitioners toward these manifestations?
 - The data that we obtained provide empirical evidence that RE inconsistency is an integral part of RE practice, and is perceived by most practitioners as a severe problem.
 - It justifies the decades' long discussion in the RE literature and the ongoing search for relevant solutions.

...

Discussion: Revisiting the RQs

- **RQ2** What are the attitudes of practitioners toward these manifestations? ...
 - The vast majority of the participants showed, at least initially, negative attitudes toward inconsistency, accompanied by emotions such as anger, shame, guilt, disappointment, and distress.

Discussion: Revisiting the RQs

- **RQ3** What strategies do practitioners think should be applied to address these inconsistency manifestations?
- **RQ4** More specifically, what are the perceptions and attitudes of practitioners with regard to inconsistency toleration as a solution strategy?
 - The main activities listed by the VPF were reflected in the strategies proposed by the interviewees, with the majority of these strategies classified to the response of resolving.
 - Only 10 out of 24 of the strategies offered by the participants included some temporary or permanent toleration of inconsistency, and the remaining strategies were the default of “fix it on sight”, which is strictly not tolerant. ...

Discussion: Revisiting the RQs

- **RQ3** What strategies do practitioners think should be applied to address these inconsistency manifestations?
- **RQ4** More specifically, what are the perceptions and attitudes of practitioners with regard to inconsistency toleration as a solution strategy? ...
 - Only after we forced interviewees to think about cases in which it makes sense to tolerate inconsistency permanently, they began to lean toward more tolerant strategies.
 - Many of these participants stressed the importance of documenting the tolerated inconsistency, as is recommended by both the VPF and the JZVF.

Discussion

- Negative attitudes of practitioners toward inconsistency pose barriers to adoption of inconsistency management paradigms.
- A thorough analysis of these attitudes, and the underlying perceptions and intuitions, is a key factor in overcoming these barriers.
- Our research provides empirical evidence of the widespread existence of RE inconsistency and demonstrates that the VPF and the ZJVF cover all manifestations obtained from our practitioners.

Discussion

- Despite the paradigm shift that was suggested in the literature over two decades ago and available inconsistency management methods, the call to change the way we think about inconsistency has not been heeded in practice. The attitudes toward inconsistency exhibited and the strategies suggested by most of our participants are consistent with the prevailing view from the 1990s that inconsistency is an “epistemic hell to be avoided at all costs”.

Discussion

- *Changing the way we think* is not always simple.
- It is not enough to rationally accept an idea that contradicts one's intuition.
- Exploring a practitioner's intuitive reactions when introducing a new paradigm is a key step toward removing the barriers of the paradigm's acceptance.

Future work

- Examining the effects of specific variables on the observed behavior patterns, for example:
 - Experience
 - Role
- Exploring decision-making patterns demonstrated by practitioners when choosing inconsistency management strategies

Future work

- Following the identification of potentially counter-intuitive principles of a paradigm one should
 - explore means for reconciling these principles
 - for example: bridging intuitive and analytical thinking (Ejersbo, Leron & Arcavi, 2014)



The End

Examples of IM tools

- **Techne**: an inconsistency-tolerant requirements modeling language
(Ernst, Borgida, Mylopoulos, and Jureta, 2012)
- **CARL**: automatic inconsistency detection in NL requirements (Zowghi and Gervasi, 2003)
- **ViewPoints**: a framework for inconsistency management in evolving requirements
(Easterbrook and Nuseibeh, 1996)