

# CAVIAAR

Cooperative **A**utomated **V**ehicle with **I**ntention **A**wareness **A**ugmented **R**eality  
HMI to model Intention Awareness in Automated  
Vehicles.



Principal Supervisor

Dr Ronald Schroeter



Co-Supervisor

Professor Andry Rakotonirainy

Mohammad Hassan  
Faramarzian Borojeni



Centre for Accident Research  
& Road Safety - Queensland (CARRS-Q)

CARRS-Q is a joint venture initiative of the  
Motor Accident Insurance Commission and  
Queensland University of Technology



# The Significance of Automated Vehicle (AV)



- ✓ More environmentally friendly (?)  
Better Trip planning
- ✓ Improved mobility (?)  
Making travel accessible to those who can't drive
- ✓ Fewer crashes (?)  
93% human error

(bitre.gov.au) choi and ji 2015, beiker 2012



Even when humans are removed from the driving task, humans will be a part of the experience and the risk.

Lync Global Volvo's vision for future domestic travel

# What's stopping people from using AVs

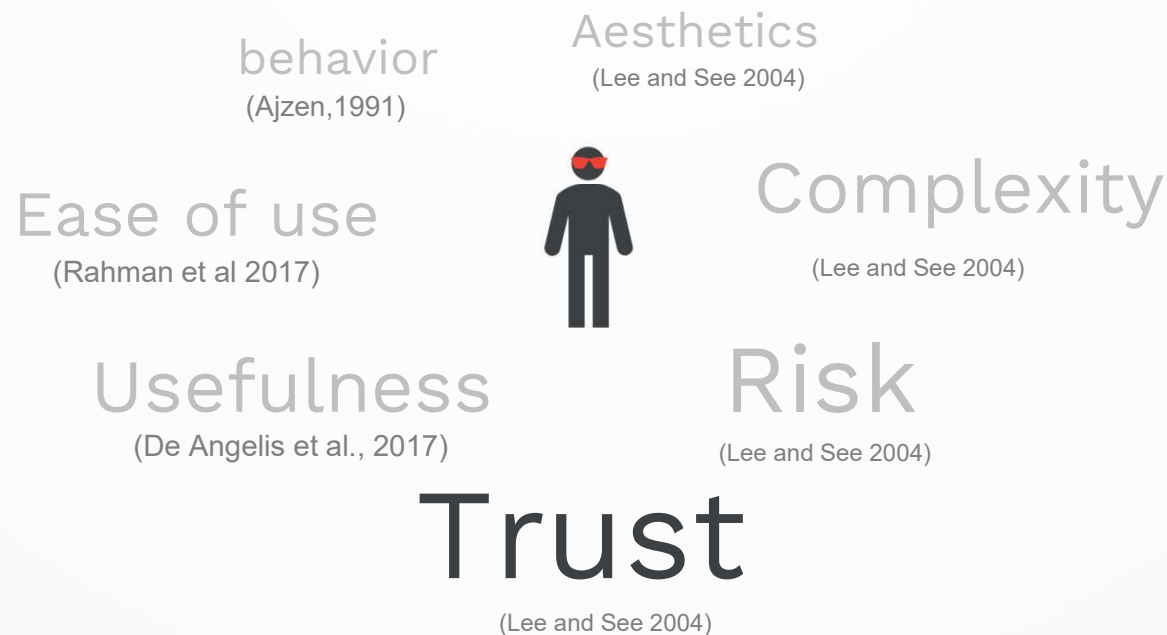


# Predictors of intent to use

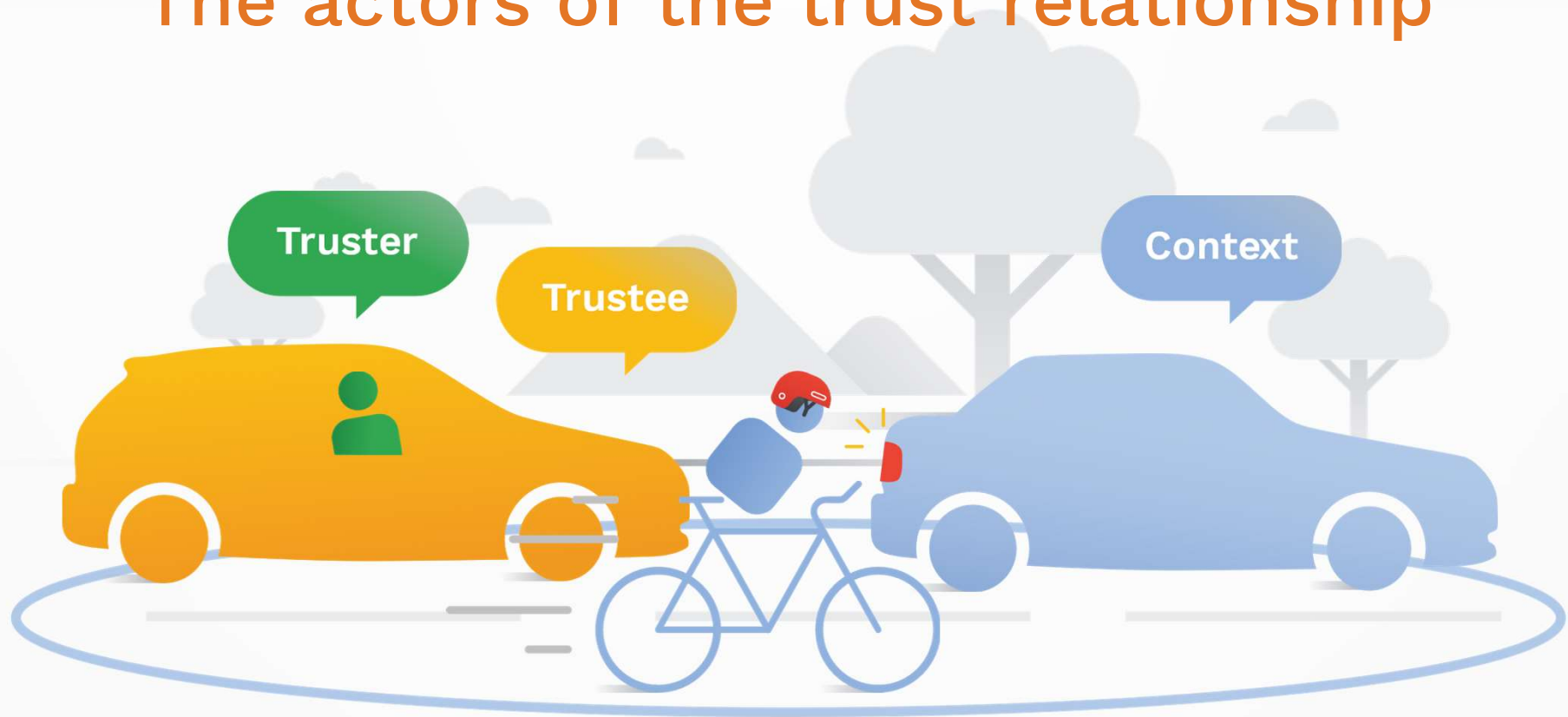
(Buckley et al 2018)

willingness of the DAU to be vulnerable to the **actions** of the AV

(Mayer, Davis, and Schoorman 1995; Choi and Ji 2015)



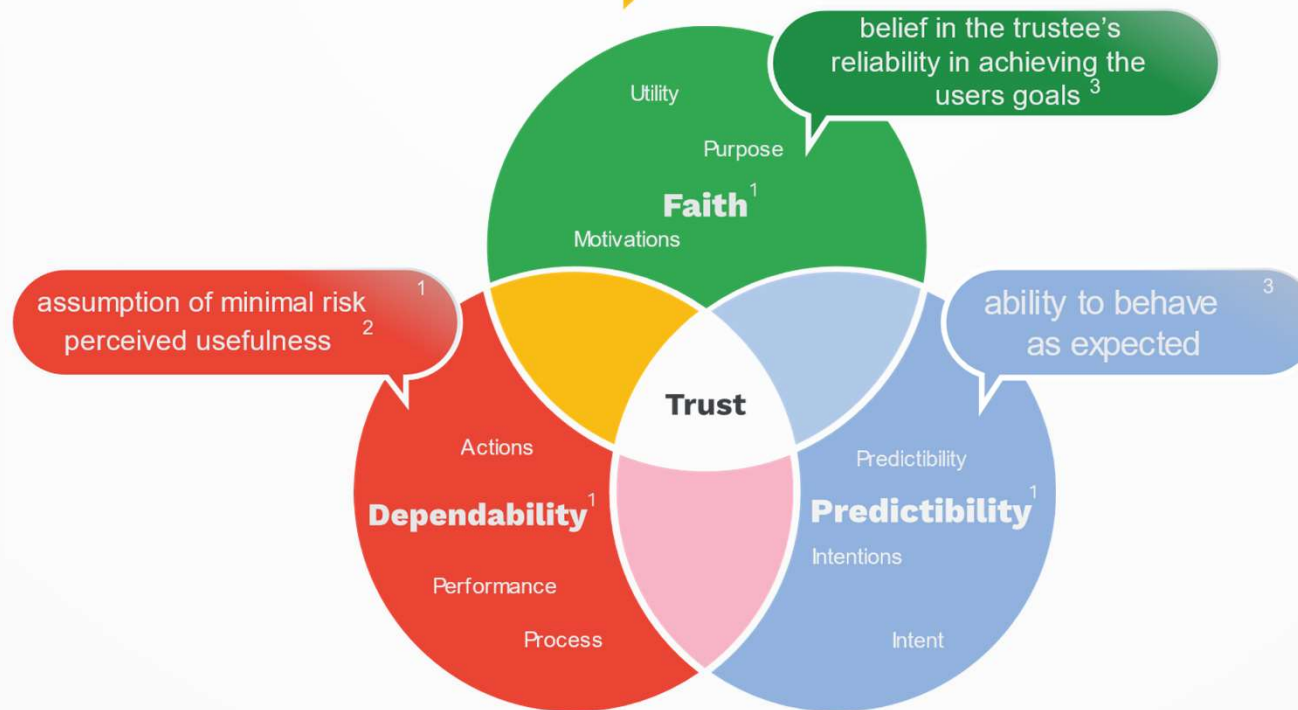
# The actors of the trust relationship



# What informs trust?



# Characteristics & information



1 (Hoc, 2000) 2 (Choi & Ji, 2015; Wu et al., 2016) 3 (Merat et al., 2017; Wu et al., 2016; Lees and Lee 2007).



# Time



## Characteristics of trust associated to vehicles actions in time

Reliability based on Vehicle's	Past Action	Future Action
Merat et al, 2017	Dependability	Motivation      Intentionality
Muir & Moray, 1996	Actions	predictability
Lee and See's 2004	Actions	Motivations      Intentions
Walker et al. 2016	Faith      Dependability	predictability
Choi and Ji 2015	Technical competence	Situation Managment system transparency
Lees and Lee 2007	Performance/Utility	Process/Predictability      Purpose/Intent
<b>Time</b>	<b>Past</b>	<b>Future</b>



Intent to use



use

# Intention



# Intention Awareness



## How AV's Intentions can inform DAU of future actions



Alert timing in driving situations (Koo et al., 2015).

# Technology-Centric Systems

Feedback



Situation Aware

Carscoop's Tesla's Autopilot video

FeedForward



Intention Aware

Porsche Augmented vision

# Human-Centered Intention Aware



# Cooperation between AV and DAU



Clear Communication



Miscommunication





# Human centric cooperation: Husband Metaphor

(Ju 2015)

..point out latent hazards that I think my husband might not see”



# Implicit and Explicit Communication of Intent

Body Language (Kinesics)



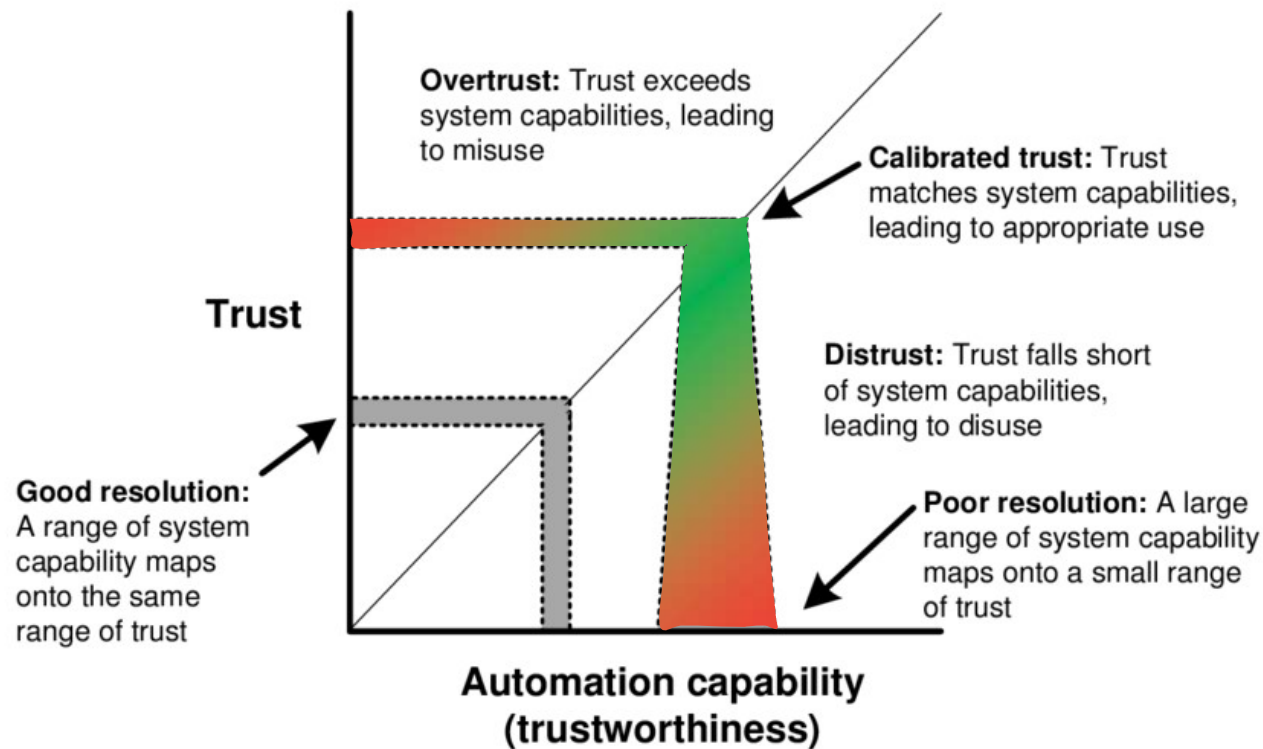
Vocal (paralanguage)



Proxemic cues and more



# AV's Intentions can calibrate trust



# Human Machine Interaction



A. Haptic controls with embedded touch controls



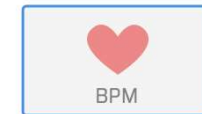
B. Touch screens with possible Haptic feedback



C. Gesture control with Visual + Aural feedback loops



D. Voice Control and Feedback



E. Soft Interactions aided by Computer vision



F. Contextual information on secondary displays (Ex. HUD's)

# Intention Awareness





# Augmented Reality



(Schroeter and Steinberger 2016).

(Spies et al. 2009; Medenica et al. 2011; Milgram, Takemura, and Utsumi 1994; Craig 2013)

# Aim

## New Knowledge:

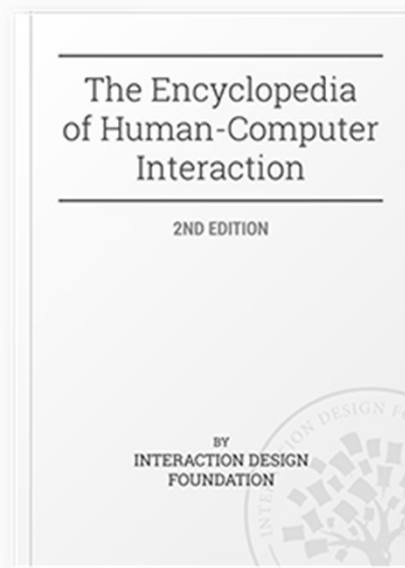
Design Theory for informing the passenger of the AV's intent through human-centric communication cues. (HCCC)

## New Design Solution:

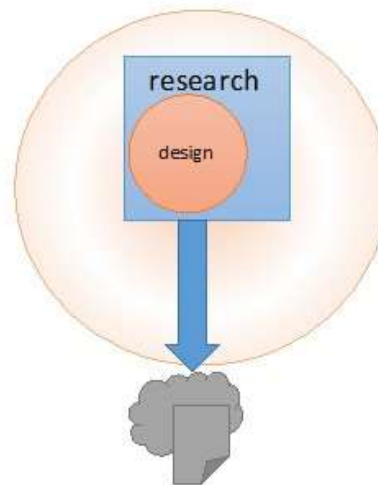
Unobtrusive AR HMI which models Intention awareness with comparable efficiency to a human driver.

# Producing design solutions

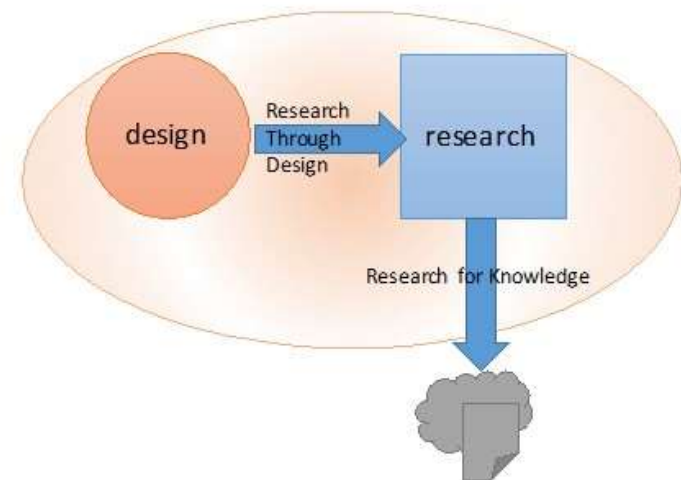
## Research through Design



design as part of research



designerly ways of doing research





# Design Theory

## “Why is it designed this way?”

### Research

produce **knowledge** for  
use by others

### Design

produce a feasible **solution**  
to **improve** a given situation

(Few 2017)

construction knowledge of the solution and why it  
works.

(Gregor et al. 2007)

A set of principles deemed effective for guiding the  
process of developing solutions for specialized  
design problem

(Walls et al. 2004)

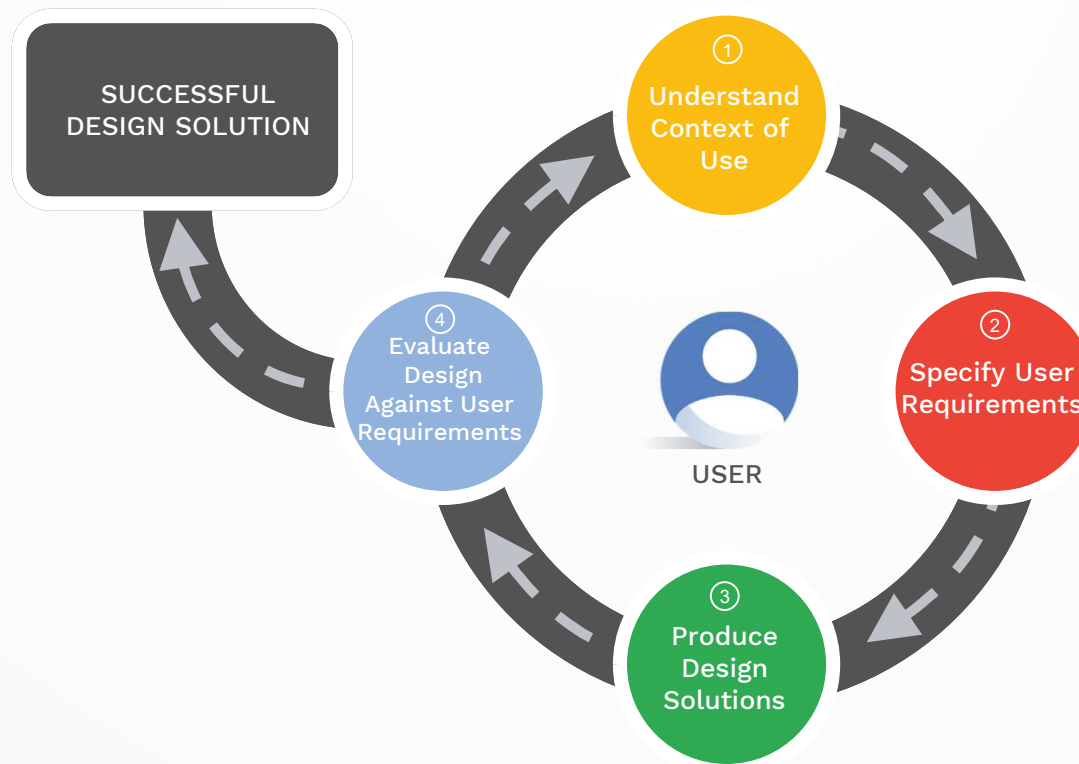


# Methodology

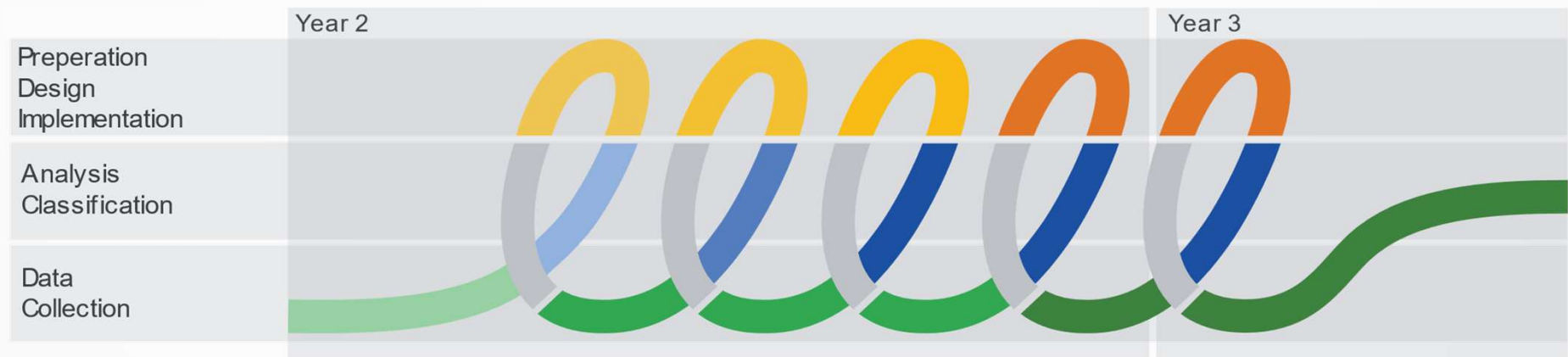


The image is a composite graphic with three horizontal sections. The top section shows a close-up of a hand with a glowing orange light on the index finger, surrounded by semi-transparent digital overlays including a world map, bar charts, and network diagrams. The middle section is a solid light gray band containing the word 'Methodology' in a bold, black, sans-serif font. Below the text is a stylized illustration of a gray brain with white neural connections, positioned above a blue folder and a laptop screen displaying a grid. The bottom section features a hand pointing at a line graph, with various data visualizations like bar charts and network diagrams overlaid in a semi-transparent manner.

# User Centered Design



# Highly Iterative process

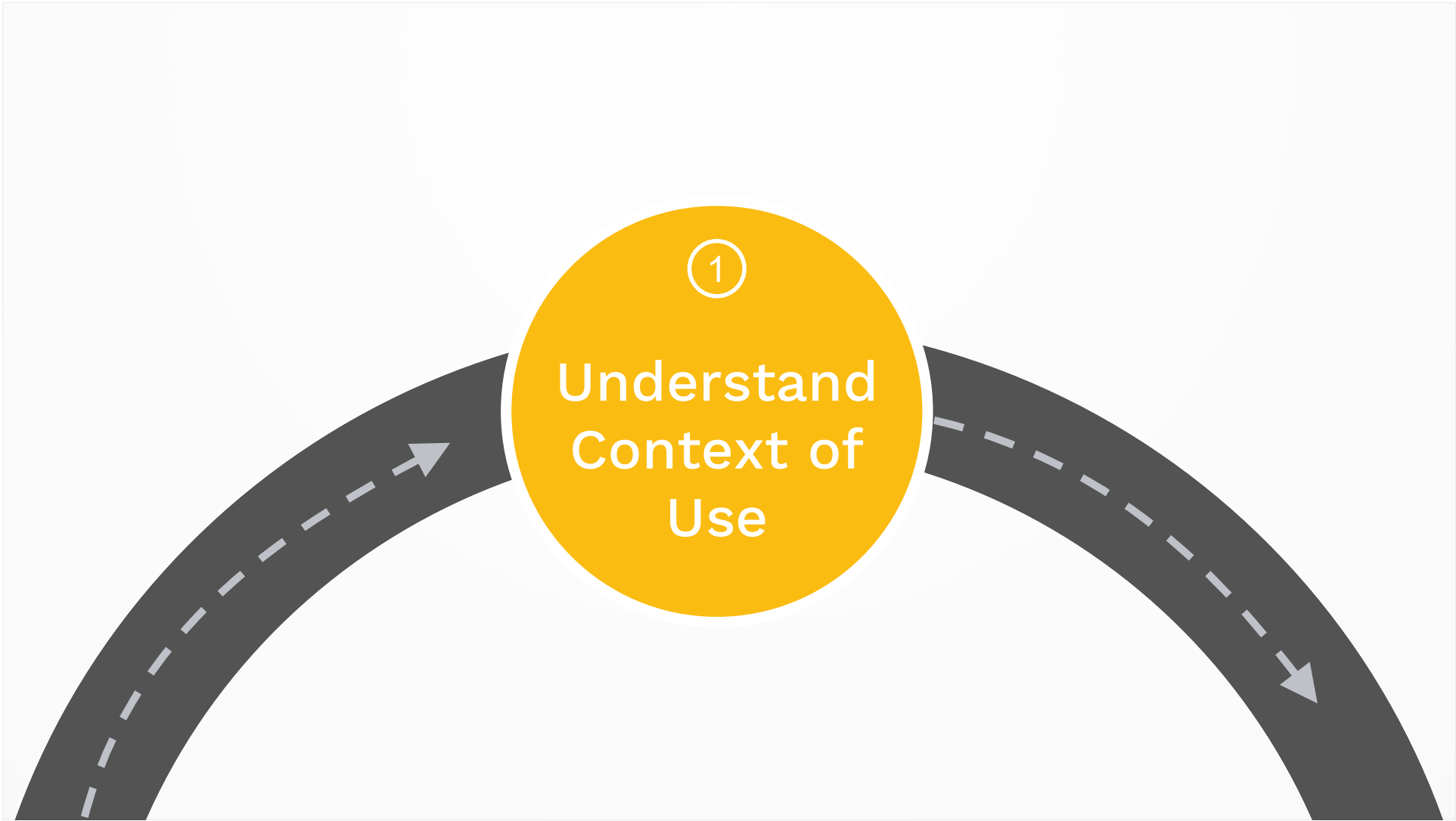


# Ethnography



①

Understand  
Context of  
Use

A diagram illustrating a step in a process. It features a central yellow circle with a white border. Inside the circle, the text "Understand Context of Use" is written in white, with a circled "1" above it. Two dark gray curved paths, resembling roads, enter the circle from the left and right sides. Each path has a dashed white line down its center and a white arrow pointing towards the circle.



# Human Centric Communication of Intent

Ethnography  
Weber's Verstehen

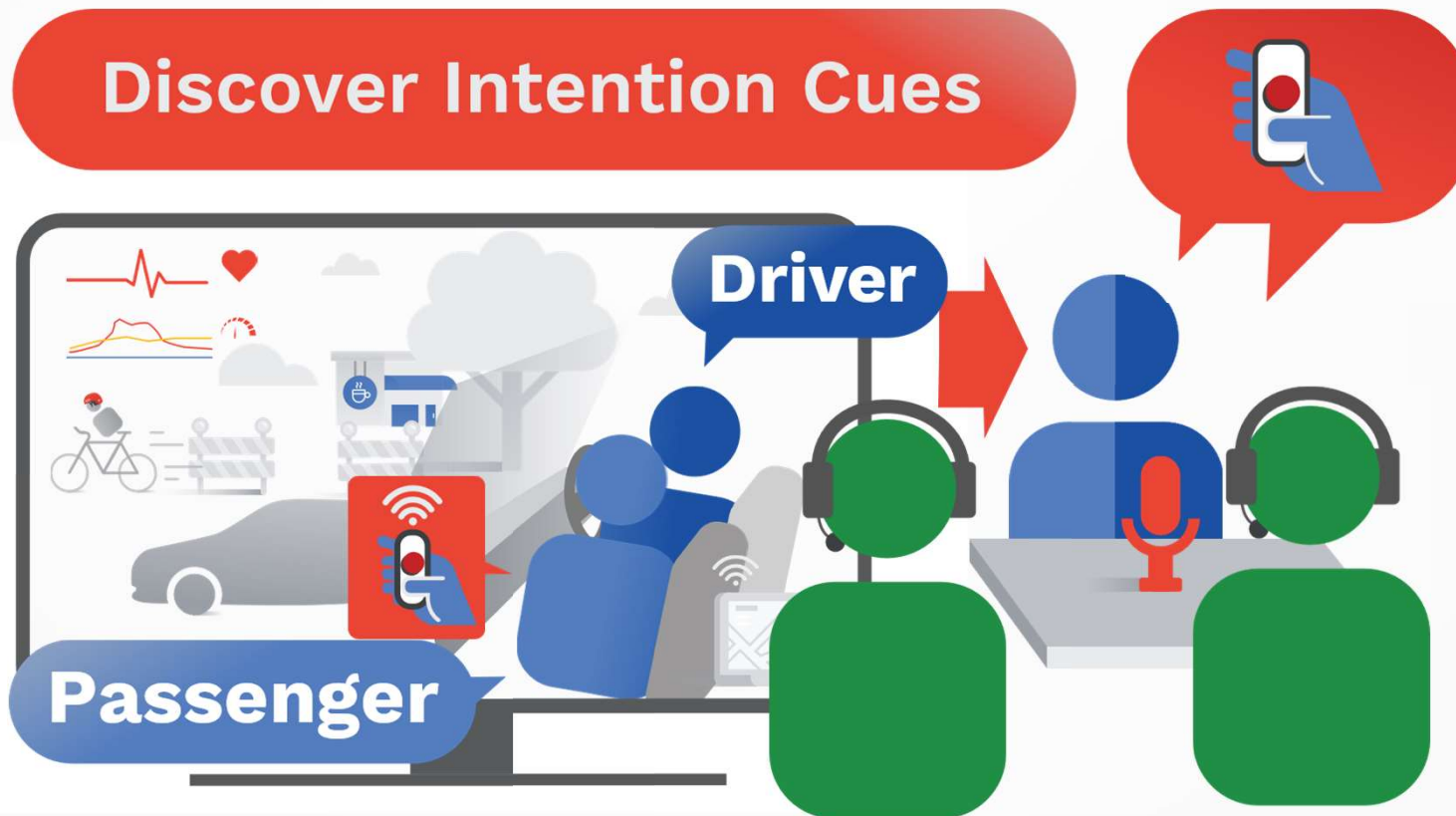
# RQ1

What are the **human-centric communication cues (HCCC)** which formulate the essence of sharing human intentions in a real-world driving context?





# Study Design



# Participants

Group 1



Partner  
Passenger

Regular  
Driver

Group 2



Stranger  
Passenger



Unfamiliar  
Driver

Group 3



Professional  
Passenger

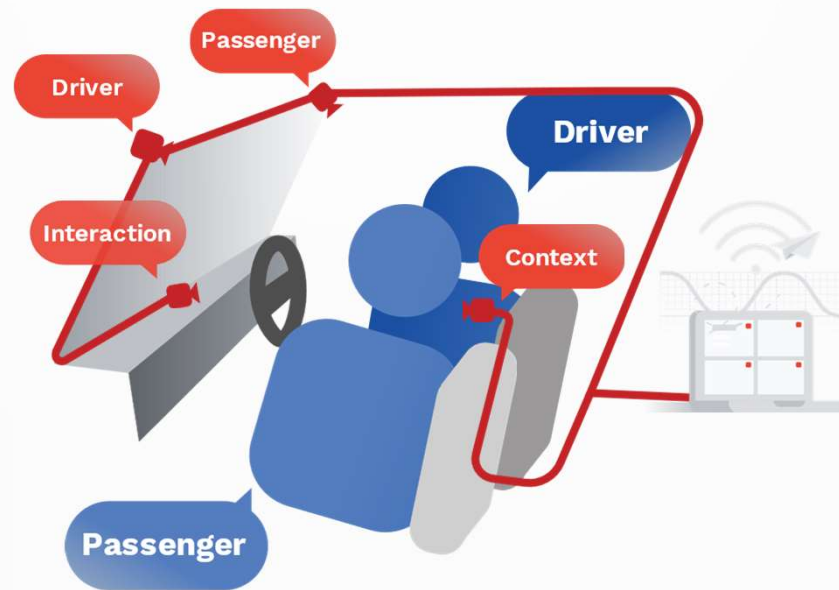


Novice  
Driver

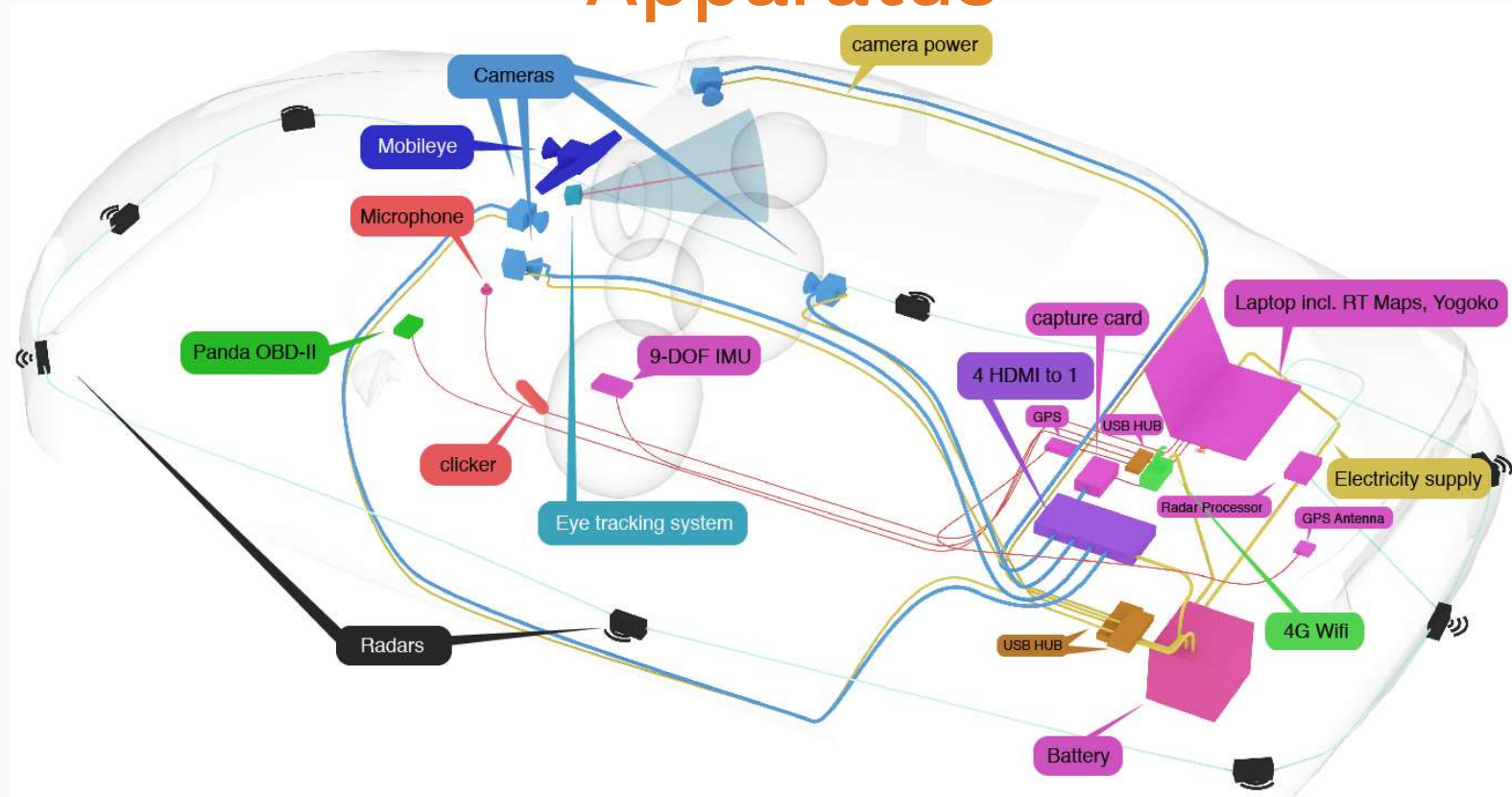
Varying degrees of trust, familiarity, ...



# Apparatus



# Apparatus



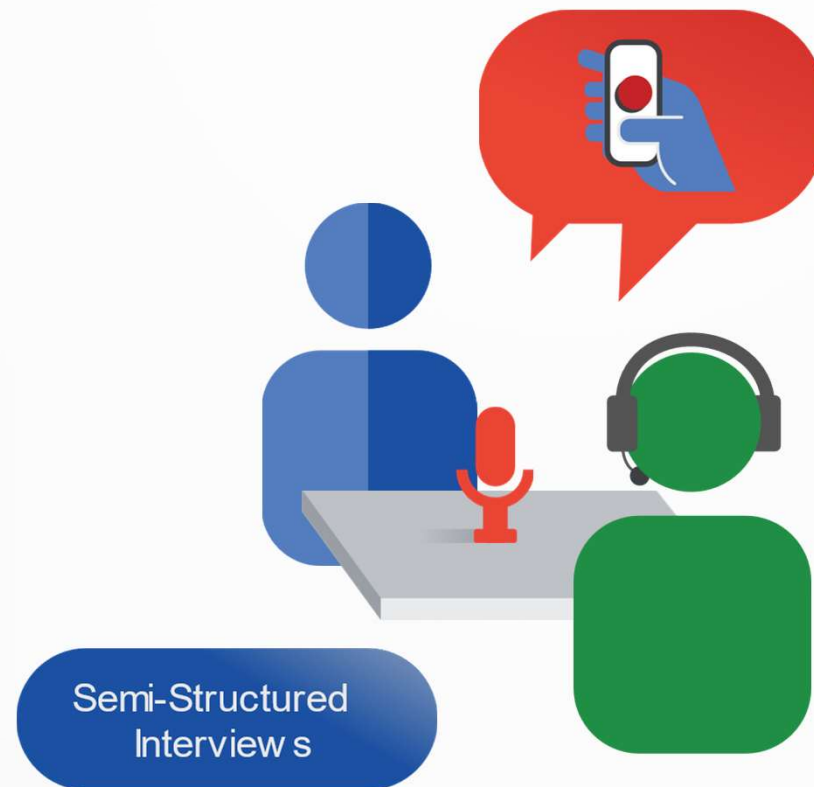
Woz way (Martelaro & Ju, 2017)



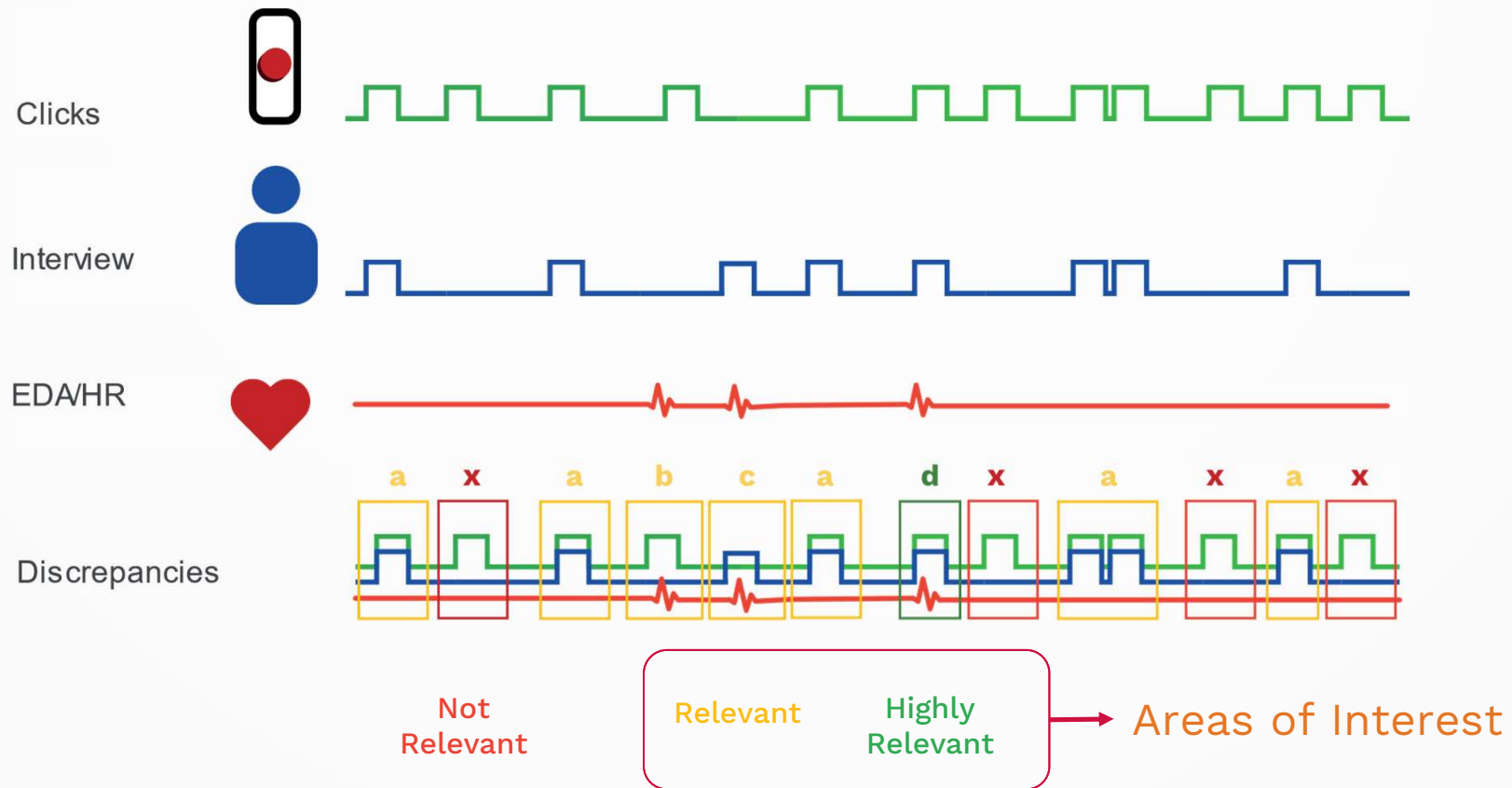




# Post Drive Review



# Analysis





## Expected outcome

### RQ 1

What are the human-centric **communication cues** which formulate the essence of sharing human intentions in a real-world driving context ?



Essence  
HCCC

### RQ 2

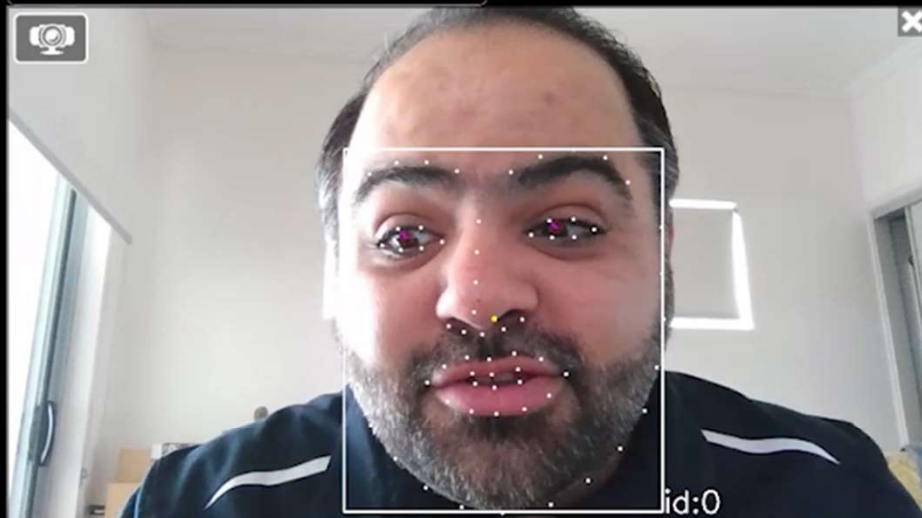
What guides the **efficiency** of communicating the human-centric abstraction of cues through an AR HMI?



Broadcasting

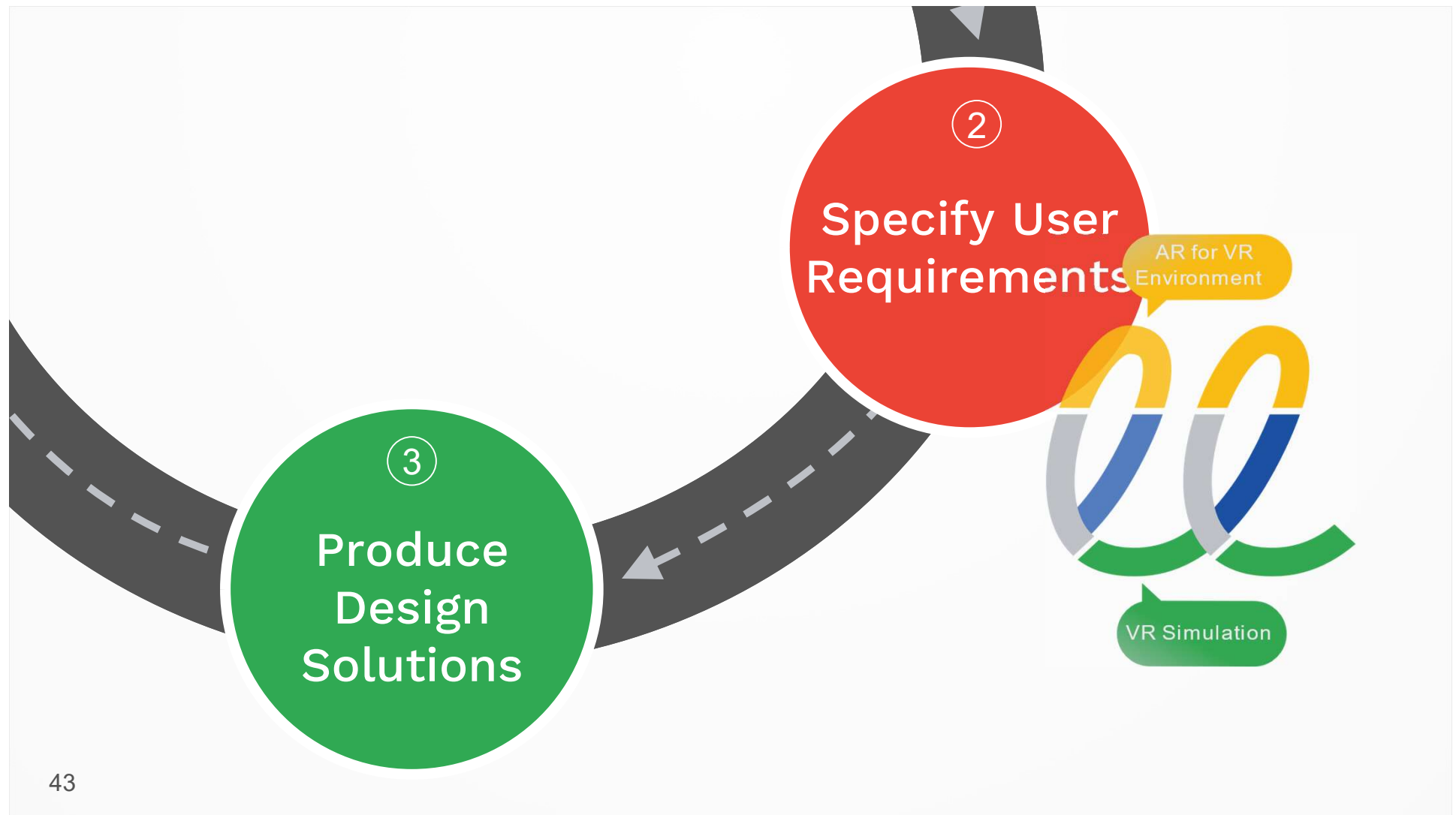


Integrated Webcam

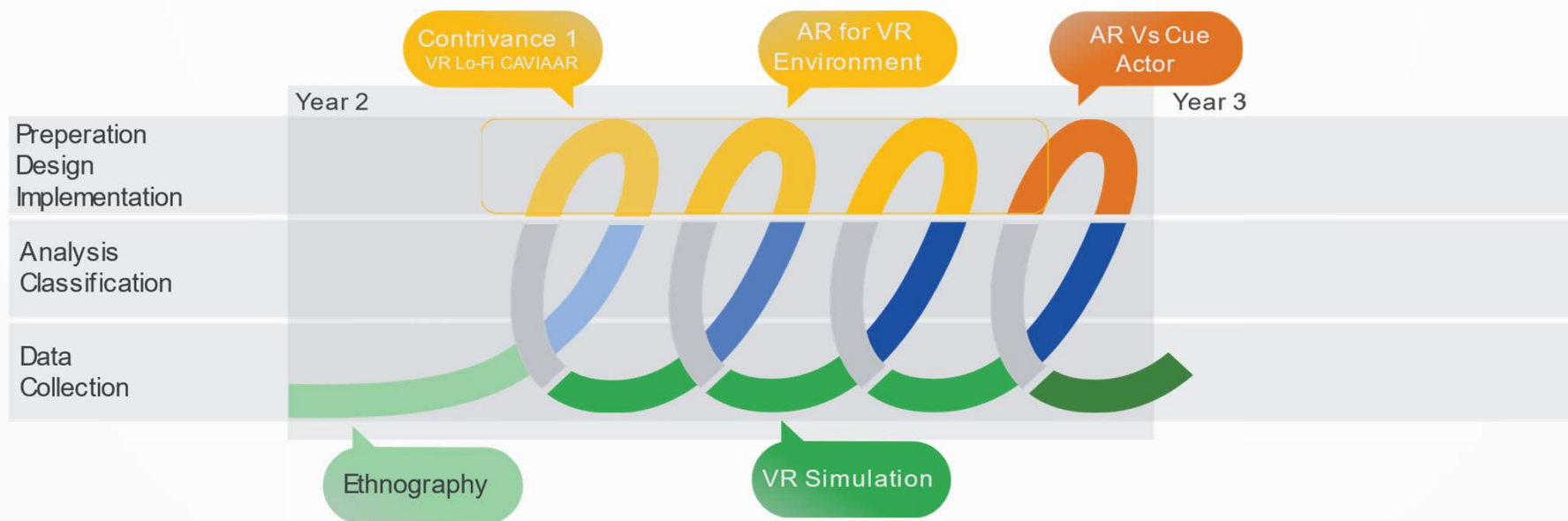


id:0



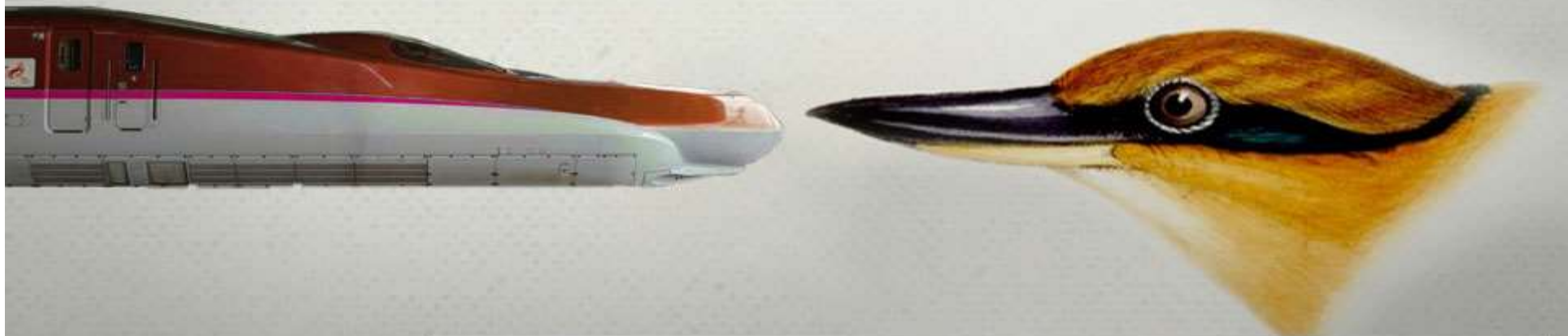


# Study 2 Timeline



# Contrivance 1

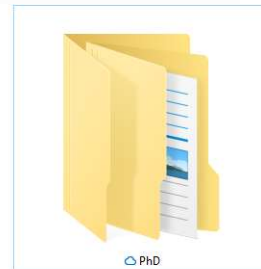
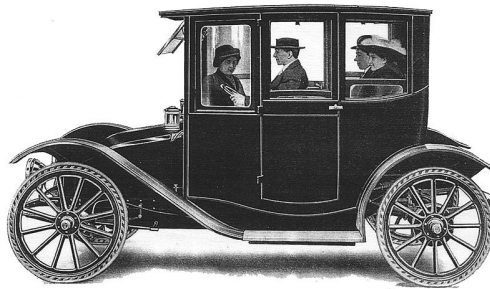
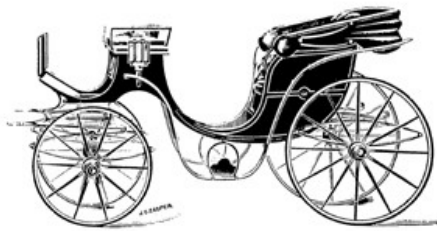
## Biomimetics



**The world is poorly designed.  
But copying nature helps.**

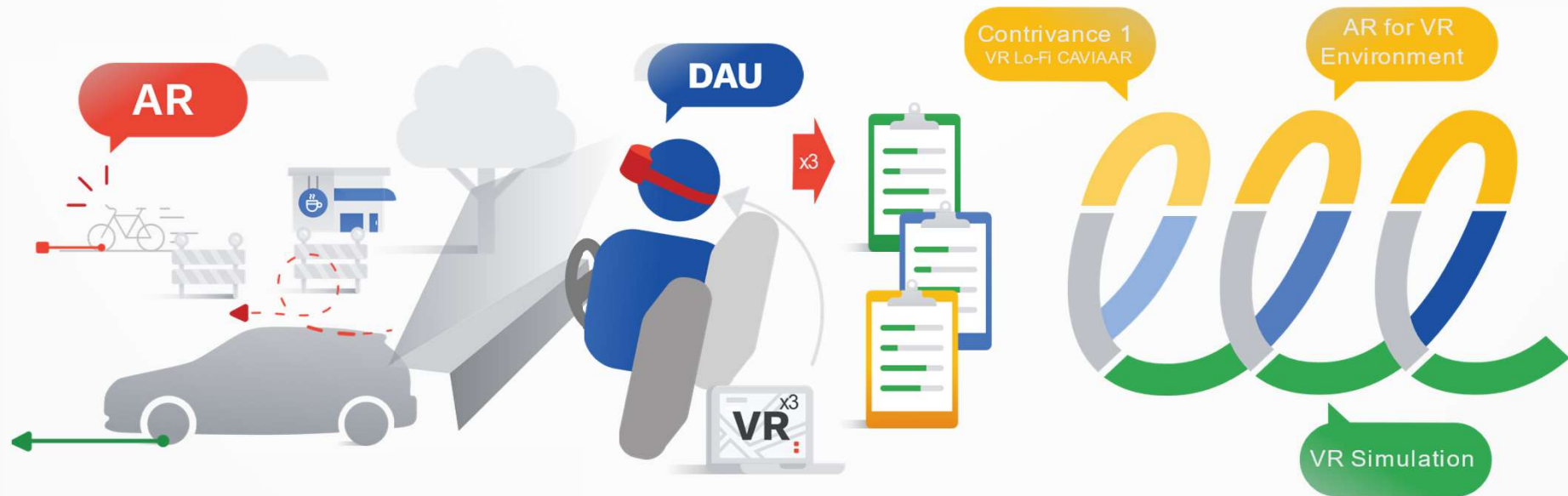
# Contrivance 1

## Skeuomorphic Design

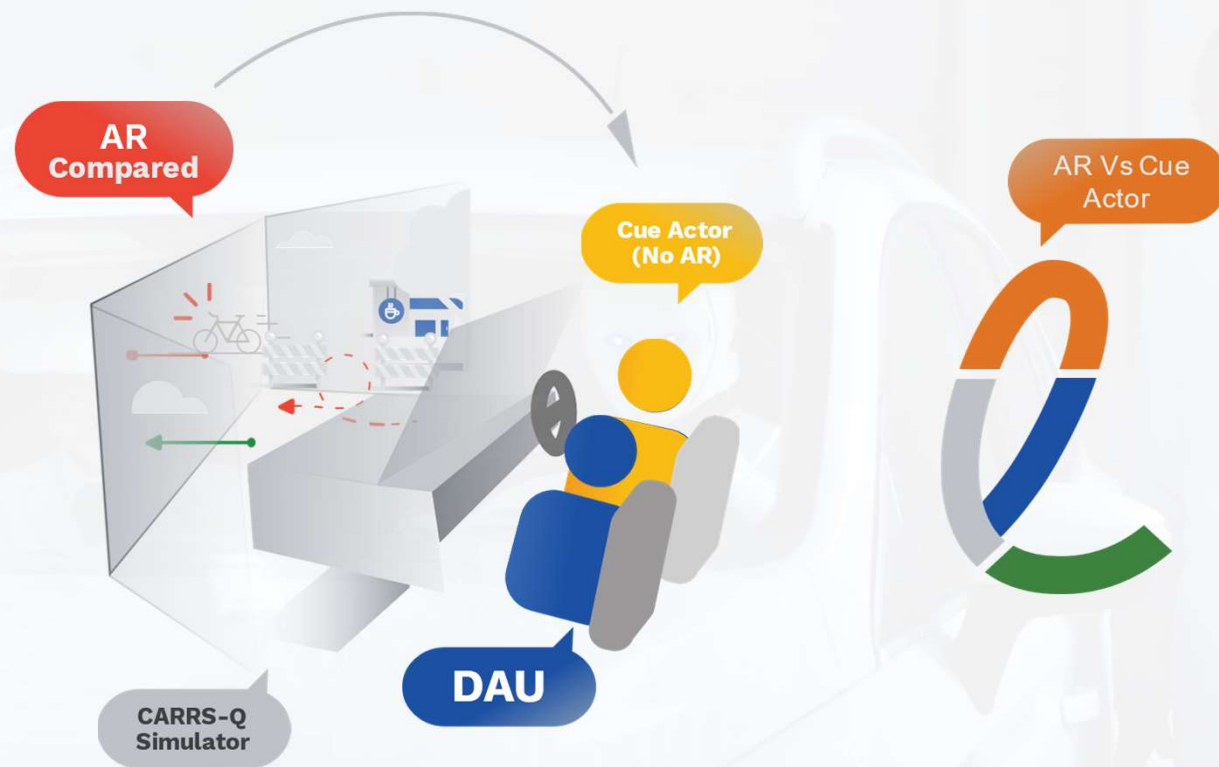




## Study 2 Design

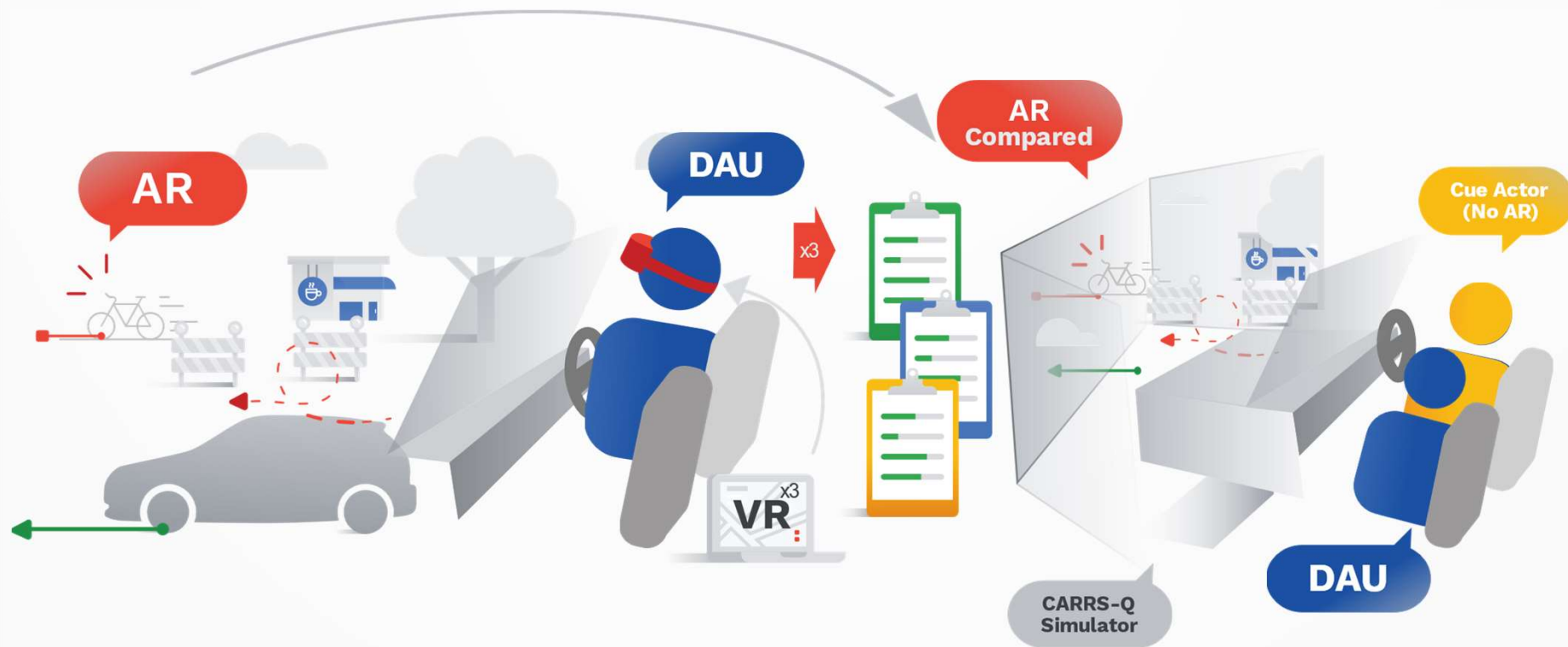


# Evaluation





## Study 2 Design



## Participants

VR

N=5

N=5

Cue Actor

N=5

N=5

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N=20

Within-Subject  
study

# Evaluation Tools

**Intent to use**



Technology  
Acceptance  
Model  
(TAM)

Richard Bagozzi (Davis 1989, Bagozzi)

**Usability**



System  
Usability  
Scale  
(SUS)

Brooke, J. (1986).

**User Experience**



Attrak+Diff

Hassenzahl, M., Burmester, M. & Koller, F. (2008)

## Expected outcome

### RQ 2

What guides the **efficiency** of **communicating** the human-centric abstraction **of cues** through an AR HMI?

**Design Principles** which form effective guidelines to inform intentions of the driver (AV) to the passenger (DAU).

# Contrivance 2:

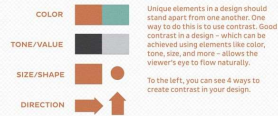
## High-Fidelity Prototype



Based on **Design Theories** discovered by **study 1 & 2**

# Contrivance 2: High-Fidelity Prototype

## CONTRAST

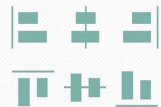


Unique elements in a design should stand apart from one another. One way to do this is to use contrast. Good contrast in a design - which can be achieved using elements like color, tone, size, and more - allows the viewer's eye to flow naturally.

To the left, you can see 4 ways to create contrast in your design.

## ALIGNMENT

Proper alignment in a design means that every element in it is visually connected to another element. Alignment allows for cohesiveness; nothing feels out of place or disconnected when alignment has been handled well.



## PRINCIPLES of DESIGN

quick reference poster

## REPETITION

Repetition breeds cohesiveness in a design. Once a design pattern has been established - for example, a dotted border or a specific typographic styling - repeat this pattern to establish consistency.

The short version?

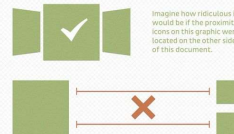
Establish a style for each element in a design and use it on similar elements.



## PROXIMITY

Proximity allows for visual unity in a design. If two elements are related to each other, they should be placed in close proximity to one another. Doing so minimizes visual clutter, emphasizes organization, and increases viewer comprehension.

Imagine how ridiculous it would be if the proximity icons on this graphic were located on the other side of this document.



a handy **paperkit** resource

## LINE

A line is a mark between two points. There are various types of lines, from straight to squiggly to curved and more. Lines can be used for a wide range of purposes: drawing a word or phrase, connecting content to one another, creating patterns and much more.

## COLOR

Color is used to generate emotions, define importance, create visual interest and more. CMYK (cyan/magenta/yellow/black) is subtractive. RGB (red/green/blue) is additive.

Some colors are warm and active (orange, red); some are cool and passive (blue, purple).

There are various color types (primary to analogous) and relationships (monochromatic to triad) worth learning more about as well.

**paperkit**  
created by Paper Leaf Design, www.paper-leaf.com

## SHAPE

Height + width = shape. We all learned basic shapes in grade school - triangles, squares, circles and rectangles. Odd or lesser seen shapes can be used to attract attention.

There are three basic types of shape: geometric (triangles, squares, circles etc.), natural (leaves, animals, trees, people), and abstracted (icons, stylizations, graphic representations etc.).

## ELEMENTS OF DESIGN

quick reference sheet

## SIZE

Size is how small or large something is; a small shirt vs. an extra large shirt, for example. Use size to define importance, create visual interest in a design (via contrasting sizes), attract attention and more.

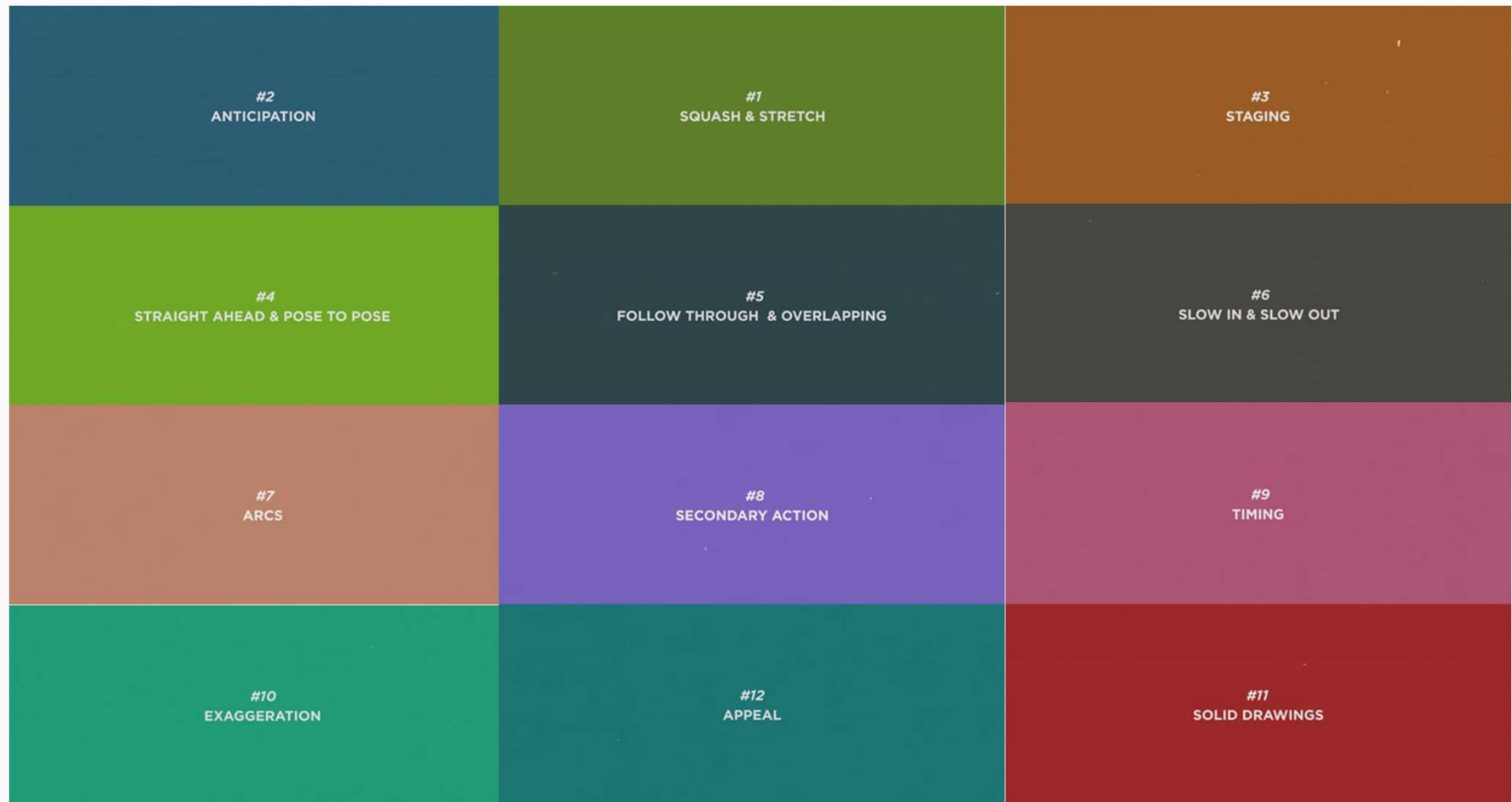
## VALUE

Value is how light or how dark an area looks. A gradient, shown above, is a great way to visualize value - everything from dark to white, all the shades in-between, has a value. Use value to create depth and light; to create a pattern; to lead the eye; or to emphasize.

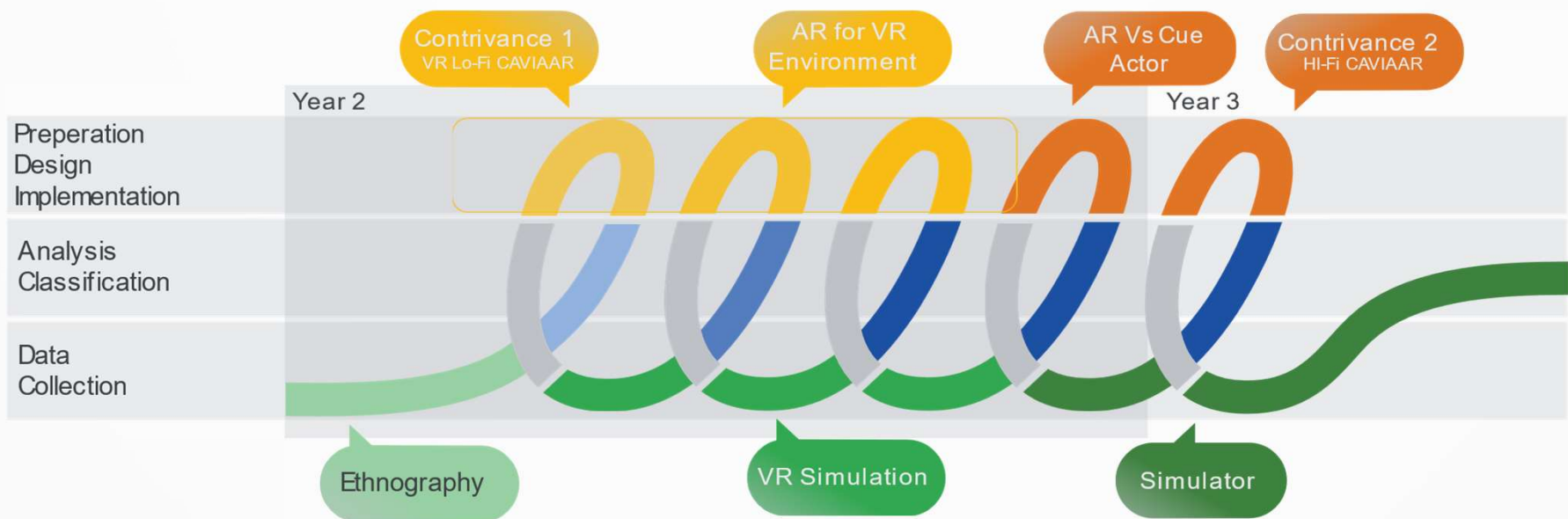


Space is the area around or between elements in a design. It can be used to separate or group information. Use it effectively to give the eye a rest; define importance; lead the eye through a design and more.

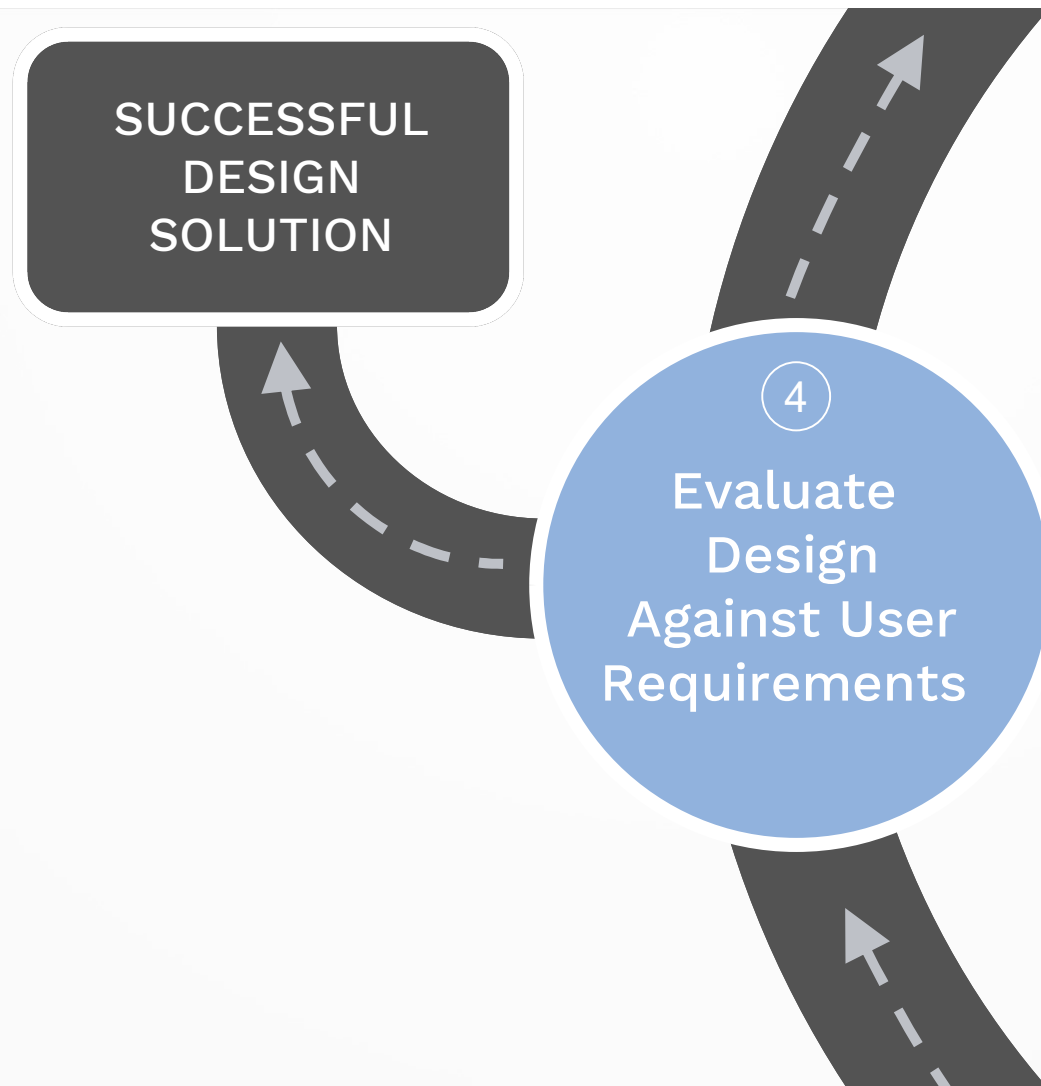
## SPACE



# Study 3 Timeline



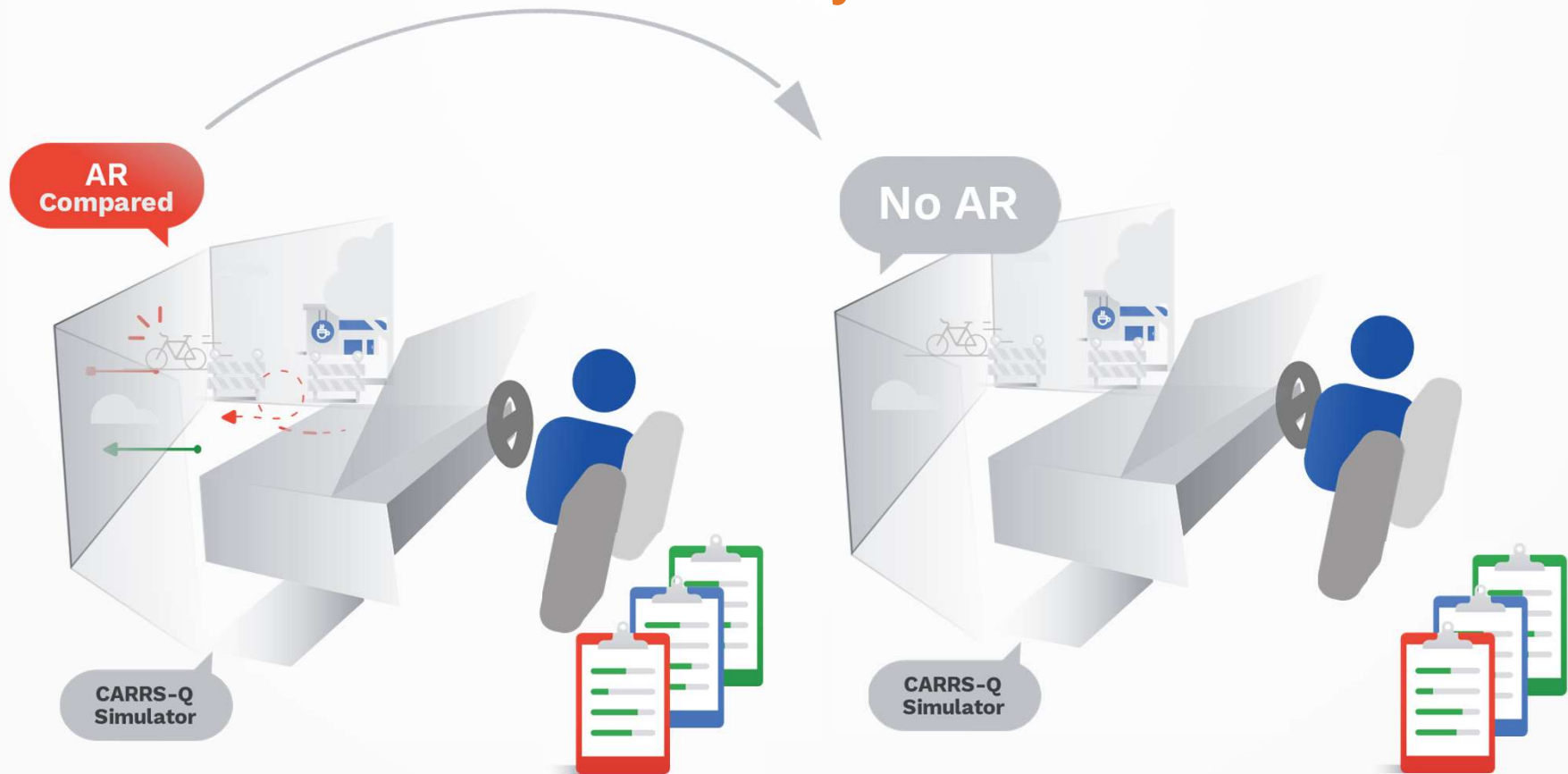




## RQ 3

What are the **effects** of **Intention awareness inducing** HMI on DAUs compared to DAUs **without** awareness of the AVs intentions?

## Study 3



# Participants

No AR

N=15

AR

N=15

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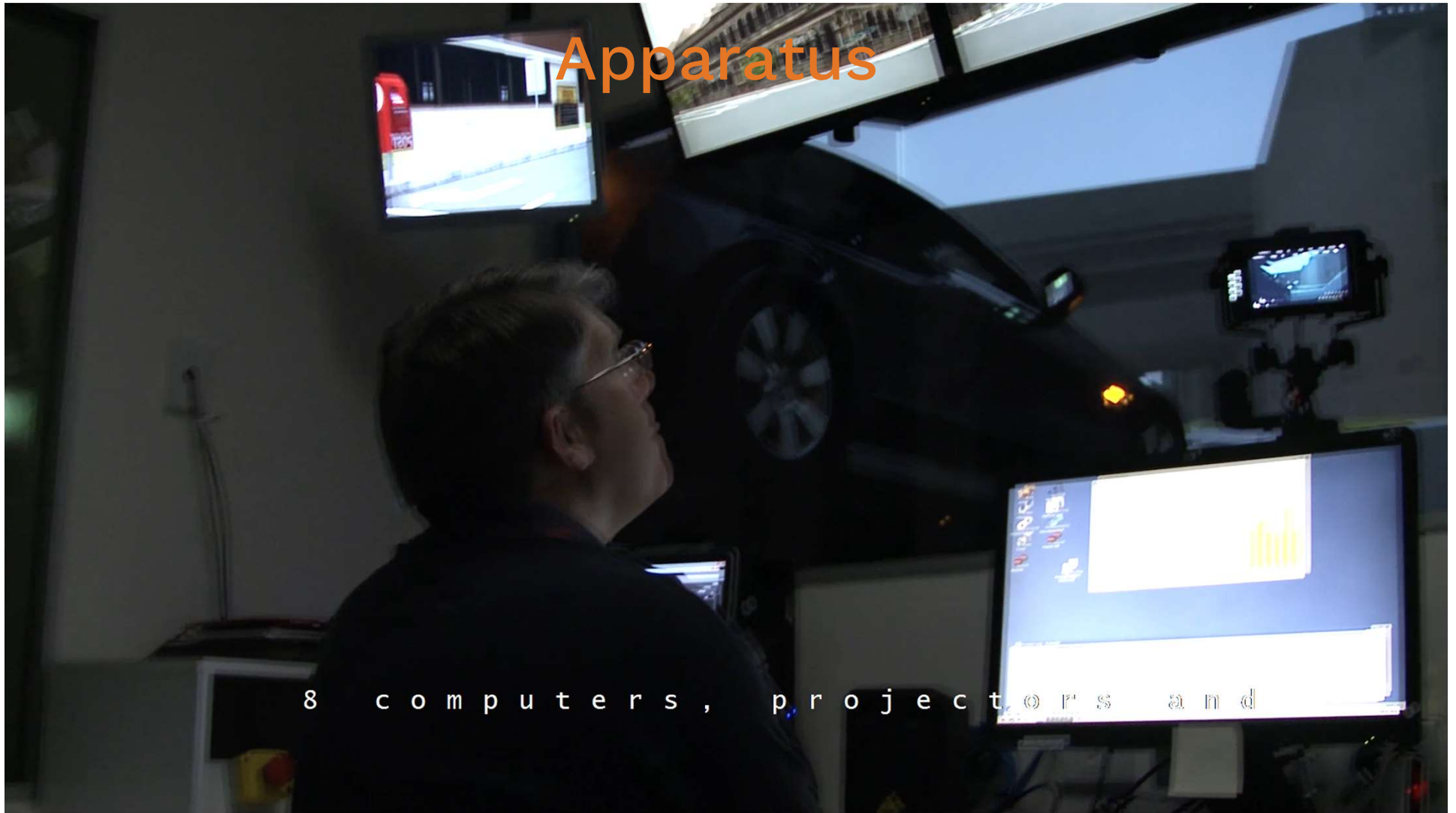
N=30

Between-Subject  
Study



# Apparatus

8 computers, projectors and



# Analysis

**Intent to use**



Technology  
Acceptance  
Model  
(TAM)

**Usability**



System  
Usability  
Scale  
(SUS)

**Trustworthiness**



Trust in  
Automation  
(TiA)

# Expected outcome

What are the **effects** of **Intention awareness** inducing HMI on DAUs compared to DAUs **without** awareness of the AVs intentions?

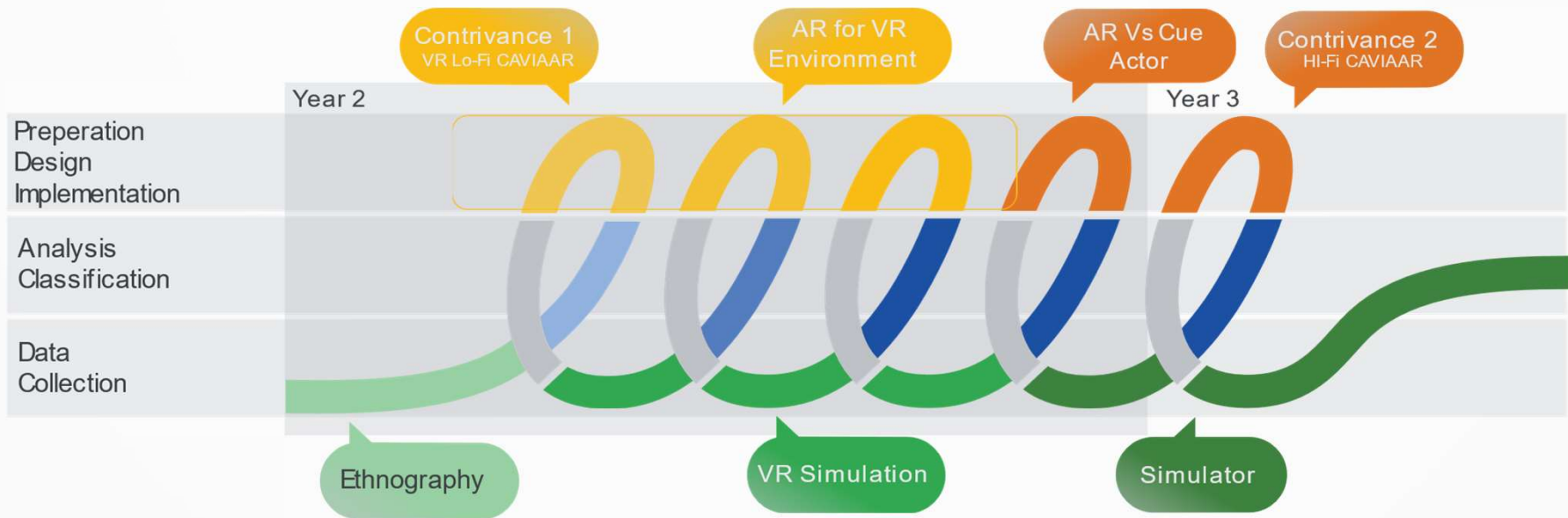


**Effects** of **Intention Awareness** inducing HMIs on DAUs.



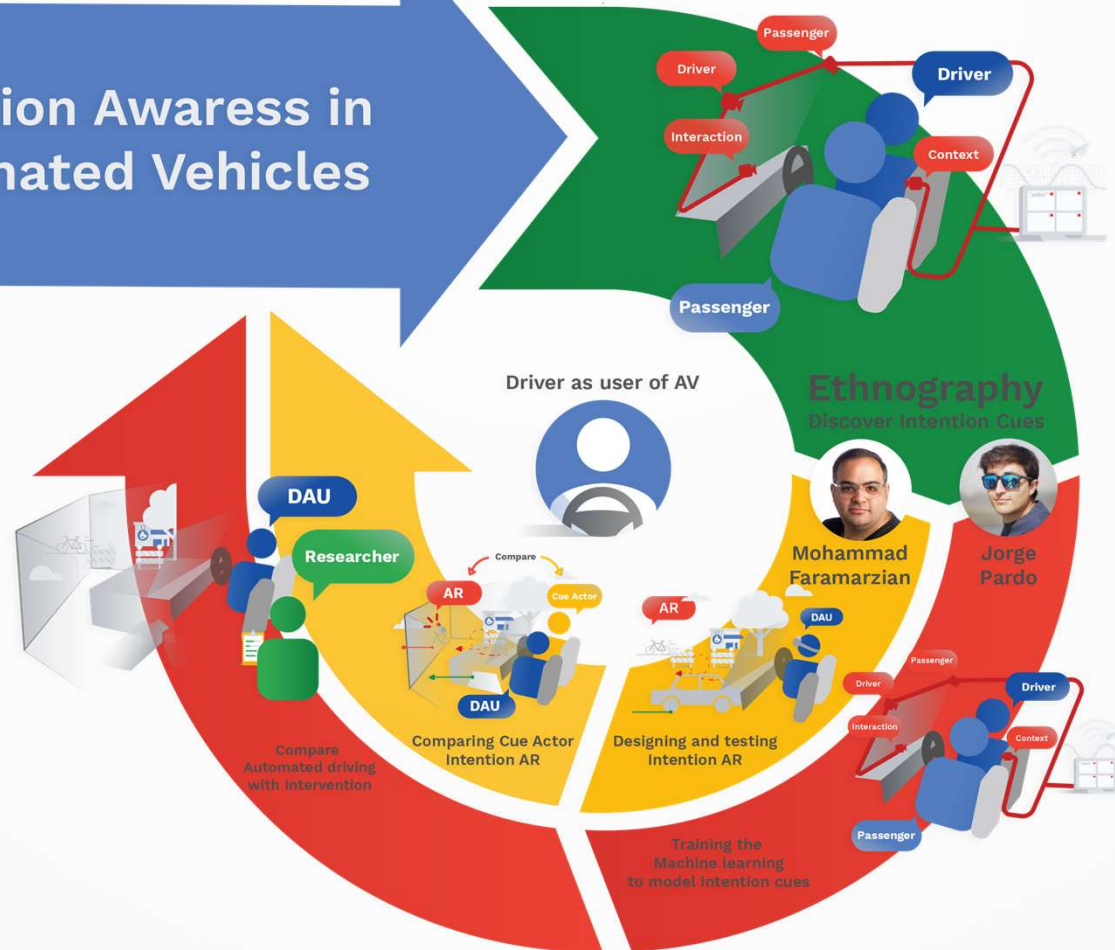
Design theories which guide an **efficient AR HMI** which models **Intention Awareness**

# Research Timeline





# Intention Awareness in Automated Vehicles



Here is to days when you let the car drive like an old friend, a designated driver or son/daughter who picks you up when you are too weary to drive.



Thank You