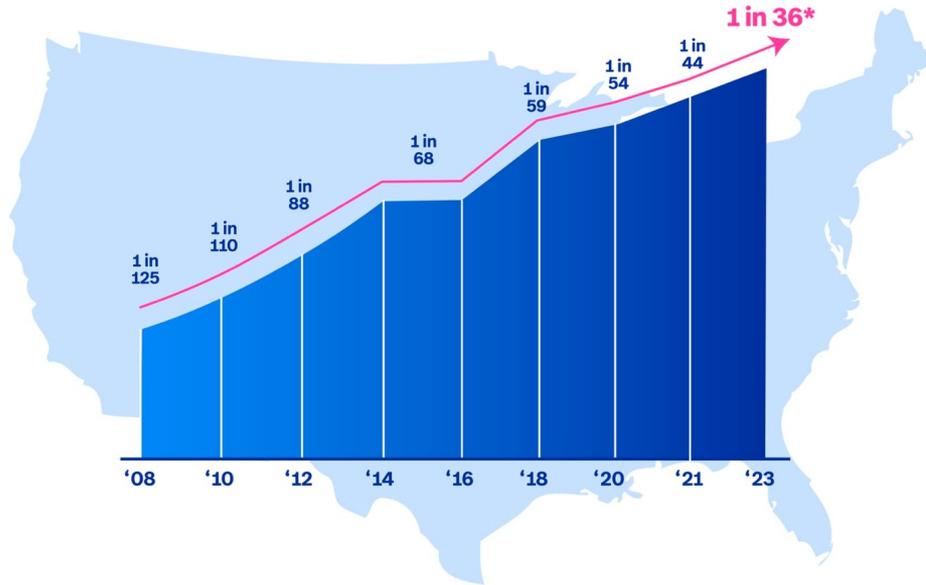# V-DAT (Virtual Reality Data Analysis Tool): Supporting Self-Awareness for Autistic People from Multimodal VR Sensor Data

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Research Background

Estimated Autism Prevalence 2023

1 in 36*

1 in 44

1 in 54

1 in 59

1 in 68

1 in 88

1 in 110

1 in 125

'08 '10 '12 '14 '16 '18 '20 '21 '23

*Centers for Disease Control and prevention (CDC) prevalence estimates (March 2023)

What about autistic adults?

Increased prevalence in autistic children

⬇

Increased number of autistic adults

Lifestyles of the autistic adults are **largely unknown**

Design Rationales of V-DAT

VR for autism population

- Various VR content has been developed for autism population
  - Self-help skills (e.g., activities of daily living skills, driving, road crossing) [1-2]
  - Social skills (e.g., job interview, facial expression recognition, social interaction) [3-4]

Previous Studies		**Strategies Reflected in V-DAT**
Limitation #1: Collected one or two sensor modalities		**Strategy #1:** Four representative sensor data
Limitation #2: Absence of a holistic approach	**Autism Stakeholders** →	**Strategy #2:** Analysis tool with data handling pipeline
VR design guideline for autism Bozgeyikli et al. (2017) [5]		**Strategy #3:** Incorporated autism-specific preferences

* **V-DAT**: **V**R **D**ata **A**nalysis **T**ool
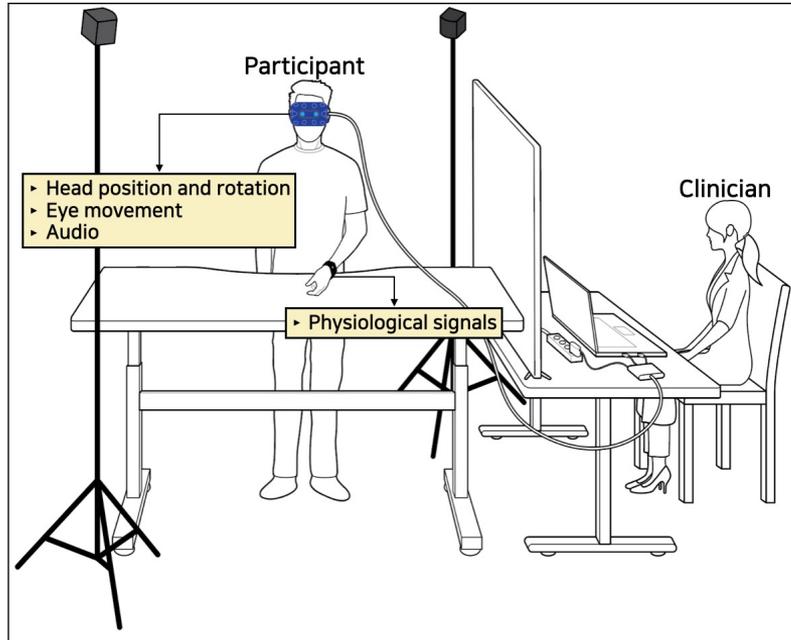
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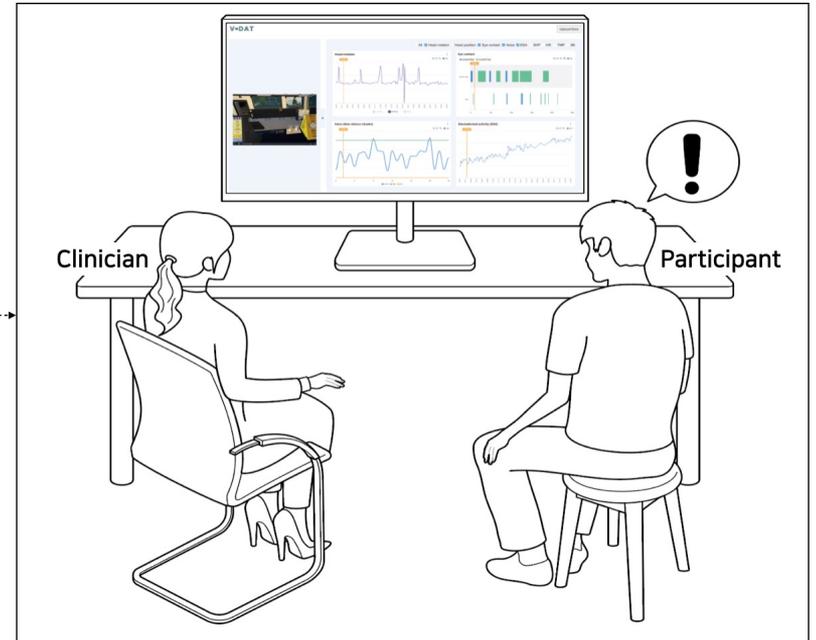 - Social skills (e.g., job interview, facial expression recognition, social interaction) [3-4]

Previous ...d in V-DAT

Limitation #1:
Collected one or tw... data

Limitation #2:
Absence of a holisti... dling pipeline

VR design guide...
Bozgeyikli et al. (20... fic preferences

V-DAT

- Effectively handle multimodal data
- Provide comprehensive visualized analysis
- Enable autistic people to reflect on their behaviors
- Help autism experts make evidence-based decisions
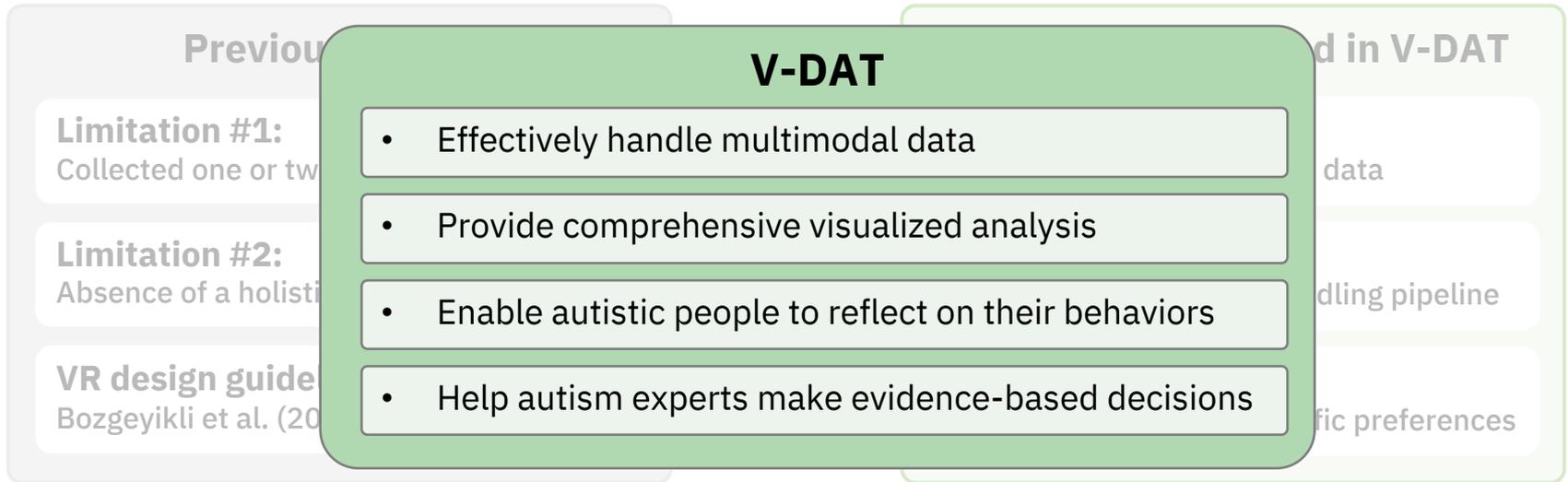
* **V-DAT**: **VR** **D**ata **A**nalysis **T**ool

V-DAT (VR Data Analysis Tool)

Data Handling pipeline

Web Interface

V-DAT: Data Handling Pipeline

① **Head movement**

- Data collection
  - ◦ Head position
    - ▪ x: left-right, y: up-down, z: forward-backward
  - ◦ Head rotation
    - ▪ Pitch (the rotation to x), roll (the rotation to y), yaw (the rotation to z)

pitch
(+/-: nodding
forward/backward)

- Data processing
  - ◦ Used raw signals for analysis to avoid misinterpretation of natural head movements

The main focus:
Awkward or excessive interactions with virtual avatars and the environment

V-DAT: Data Handling Pipeline

① **Head movement**

- Data collection
  - Head position
    - x: left-right, y: up-down, z: forward-backward
  - Head rotation
    - Pitch (the rotation to x), roll (the rotation to y), yaw (the rotation to z)

roll
(+/-: tilting head
to the left/right)

- Data processing
  - Used raw signals for analysis to avoid misinterpretation of natural head movements

The main focus:
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V-DAT: Data Handling Pipeline

① **Head movement**

- Data collection
  - Head position
    - x: left-right, y: up-down, z: forward-backward
  - Head rotation
    - Pitch (the rotation to x), roll (the rotation to y), yaw (the rotation to z)

yaw
(+/-: standing upright and looking to the left/right)

- Data processing
 - Used raw signals for analysis to avoid misinterpretation of natural head movements

The main focus:
Awkward or excessive interactions with virtual avatars and the environment

V-DAT: Data Handling Pipeline

② **Eye movement**
- Data collection
  ◦ Collected eye gaze origin, normalized gaze direction, eye openness
- Data processing
  ◦ Set the faces of virtual avatars as Region of Interests (ROIs)
  ◦ Used the Unity3D box collider to measure whether the user is gazing at ROI
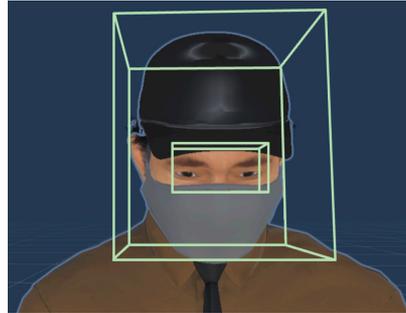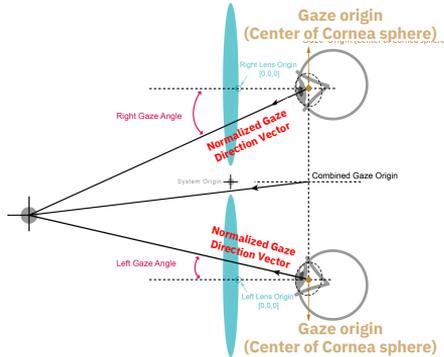
Box collider in Unity3D

$$CS(g) = \begin{cases} 0 & \text{if, } g \neq ROI_n \\ n & \text{if, } g = ROI_n \end{cases}$$

$CS(g)$ = conflict signal function
ROI_n = the n number of ROIs

The main focus:
The degree of eye contact and duration when interacting with virtual avatars

V-DAT: Data Handling Pipeline

③ **Audio**

- Data collection
    - Used beamforming technology with the HMD microphone to exclusively collect the voices from the participant
- Data processing
    - Used decibels relative to full scale (dBFS; derived from dB)
    - Extracted only the voices of the participants using dBFS
        - Empirically checked dBFS from -80 ~ -20
        - Set the threshold (dBFS = -45) of being silence or not
            - ➢ dBFS > -45: Best extracts the spoken voice and the murmur and filler words

dBFS = -50

dBFS = -45

> **The main focus:**
> Voice volume control when communicating with virtual avatars

V-DAT: Data Handling Pipeline

④ **Physiological signals**
- Data collection
  - Collected five types of sensors (EDA, BVP, TMP, IBI, and HR)
    - Commonly employed in VR research for autistic people
    - Used Empatica E4 wristband
    - HR can be additionally obtained by dividing the IBI value by 60
- Data processing
  - Used MS Azure to detect anomaly points from the five types of sensors
    - V-DAT displays those points on the visualization

Empatica E4 wristband

> **The main focus:**
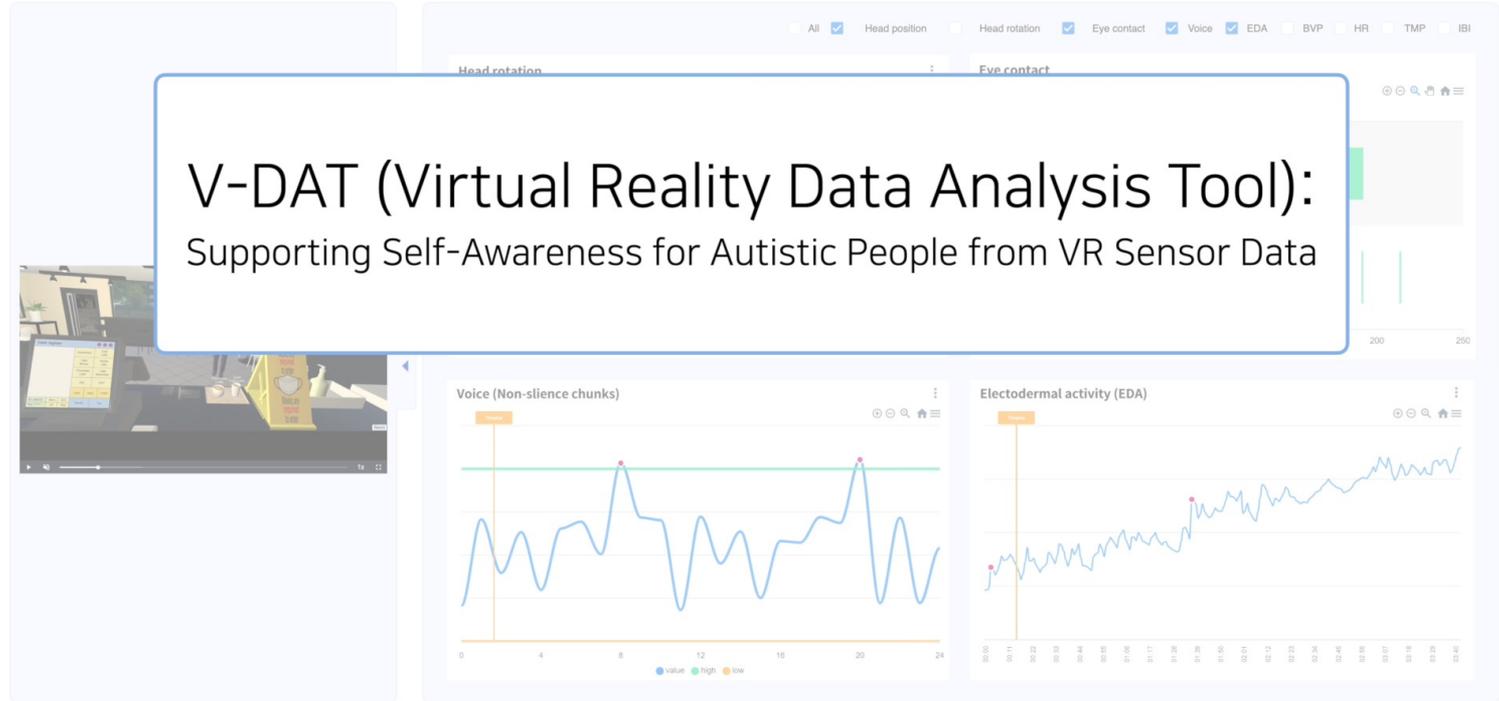> Training moments that exhibit abnormal physiological reactions (e.g., anxiety)

Synchronization of four sensor modalities
- Using Flask, aligned HMD and E4 wristband data on a single timeline.
- Scheduled requests to handle E4 server's single-message and simultaneous request limitations before VR content starts.
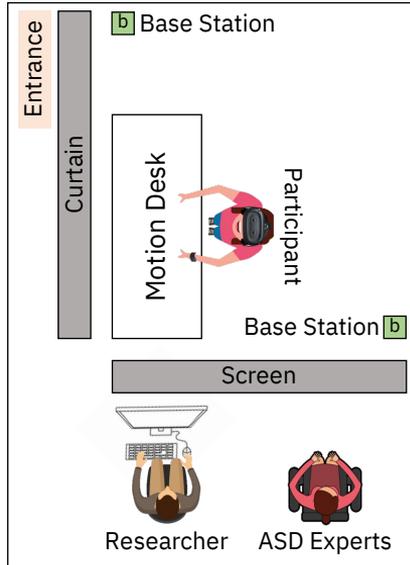
V-DAT: Web Interface

V-DAT (Virtual Reality Data Analysis Tool):
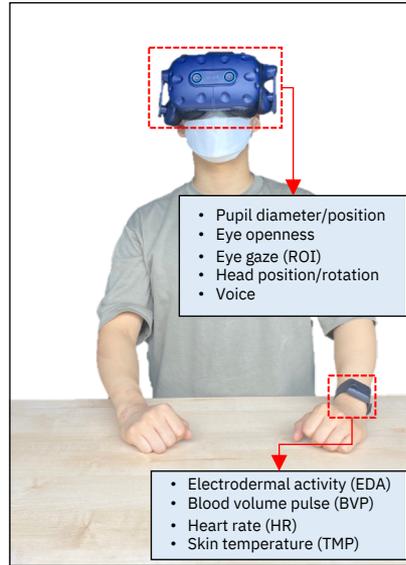Supporting Self-Awareness for Autistic People from VR Sensor Data

Case Study with Autistic People

Participants

- 20 Autistic participants (20-39 years)
- 5 autism experts who were not involved in the initial design process of V-DAT

Experiment environment

Base Station
Entrance
Curtain
Motion Desk
Participant
Base Station
Screen
Researcher
ASD Experts

Collected sensor data

- Pupil diameter/position
- Eye openness
- Eye gaze (ROI)
- Head position/rotation
- Voice

- Electrodermal activity (EDA)
- Blood volume pulse (BVP)
- Heart rate (HR)
- Skin temperature (TMP)

A participant experienced VR training

Head mounted display (HMD)

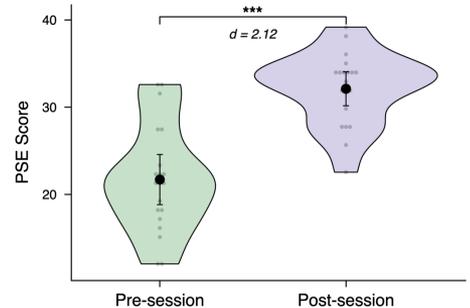E4 wrist band

Results from VR Training Review

The increased Perceived Self-efficacy (PSE) scale

- The PSE scores significantly increased after the V-DAT experience
  - before = 21.40, after = 32.20; $t(38) = 2.73$, $d = 2.12$, $p < 0.05$

High reliability supported by comprehensive data

- Increased participant's confidence and highlighted areas for more practice
  - **Informative aspect:** Participants could evaluate behaviors and compare visualizations with their thoughts
  - **Reliability:** The clinician thoroughly presented training results with the help of synchronized visualizations and a video

> "*I've often been scolded by my parents for **speaking too loudly in public or not making eye contact when talking to someone**. So, I was worried during this training that my voice might have been too loud in some parts or that I might not have made eye contact. However, I was able to **gain confidence after seeing the objective evidence** that I actually did quite well* (P-15)."
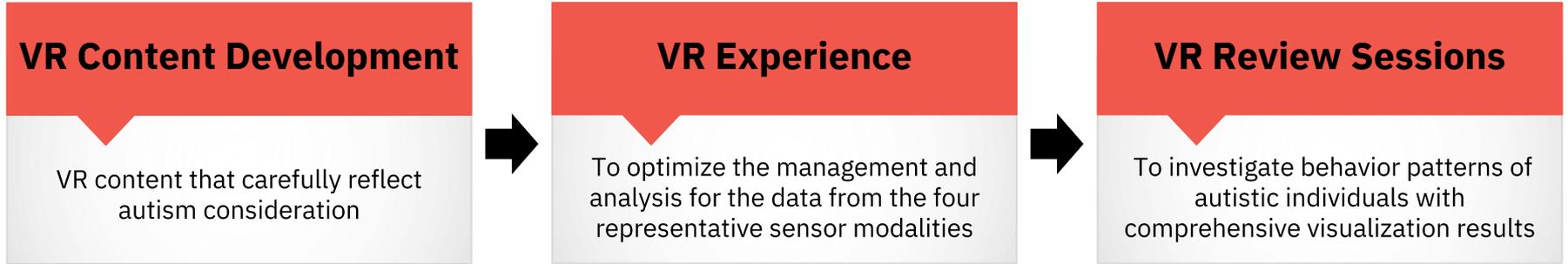
Results from Autism Expert Interviews

Data-driven clinical decision supporting tool

> "*Many people find it difficult to make eye contact and have a lot of social anxiety. However, it's quite* **limited to knowing specifically what causes them to be nervous and what physical or psychological changes occur when anxiety is amplified**. *[...] Eye contact, and excessive and awkward gestures are the tasks I usually observe or sometimes check with recorded videos. This system enables repetitive VR training in a fully controlled situation, visualizes, and provides training results at a glance. A system like this would be helpful and save me a lot of time* (E-3, Therapist)."

Bridging the gap between outpatient clinics and autism care centers

- **Psychiatrists:** Limited by short outpatient times, focusing on prescriptions and major issues like aggressive behavior.
- **Therapists:** Often handle challenging behaviors of autistic people, but struggle to pinpoint causes due to lack of objective measures
- V-DAT could fill this gap in three ways:
    1) Enables quantitative investigation of underlying causes in autistic behaviors.
    2) Supports doctors' clinical decisions with V-DAT's quantitative evidence.
    3) Provides synchronized visualizations with training videos for reliability.

Conclusion

VR Content Development	VR Experience	VR Review Sessions
VR content that carefully reflect autism consideration	To optimize the management and analysis for the data from the four representative sensor modalities	To investigate behavior patterns of autistic individuals with comprehensive visualization results

Key takeaways

- **Identified core VR sensor modalities:**
  - Four essential sensor modalities used in VR studies for autism were detailed, emphasizing their unique characteristics and processing methods.
- **Confirmed the feasibility of V-DAT:**
  - Integrated with a VR sensor data handling pipeline to effectively utilize multiple sensor signals.
- **Highlighted diagnostic and intervention potential of V-DAT:**
  - Comprehensive visualizations can assist in studying autistic behaviors, and a case study showcased its potential for meaningful interventions and diagnostics.

Q & A