

# Can Augmented Reality Enhance Checklist Adherence in Critical Operating Room Scenarios? STPA Perspective

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**HARVARD**  
MEDICAL SCHOOL



**Mass  
General  
Brigham**



Nurse

Surgeon

Anesthesiologist



# Crisis in OR



**READ OUT LOUD:**  
**Has somebody called for help?**

**Who is going to be the team leader?**

Air Embolism	1
Anaphylaxis	2
Bradycardia - Unstable	3
Cardiac Arrest - Asystole/PEA	4
Cardiac Arrest - VF/VT	5
Failed Airway	6
Fire	7
Hemorrhage	8
Hypotension	9
Hypoxia	10
Malignant Hyperthermia	11
Tachycardia - Unstable	12

All reasonable precautions have been taken to verify the information contained in this publication. The responsibility for the interpretation and use of the material lies with the reader.

# Motivation



How STPA can help to better understand OR crises/ needs assessment for designing support tools



Design and test of an Augmented Reality-based support tool (immersive checklist) to enhance adherence to best practices

# System-Theoretic Process Analysis (STPA)

STPA is a technique for development and safety assessment

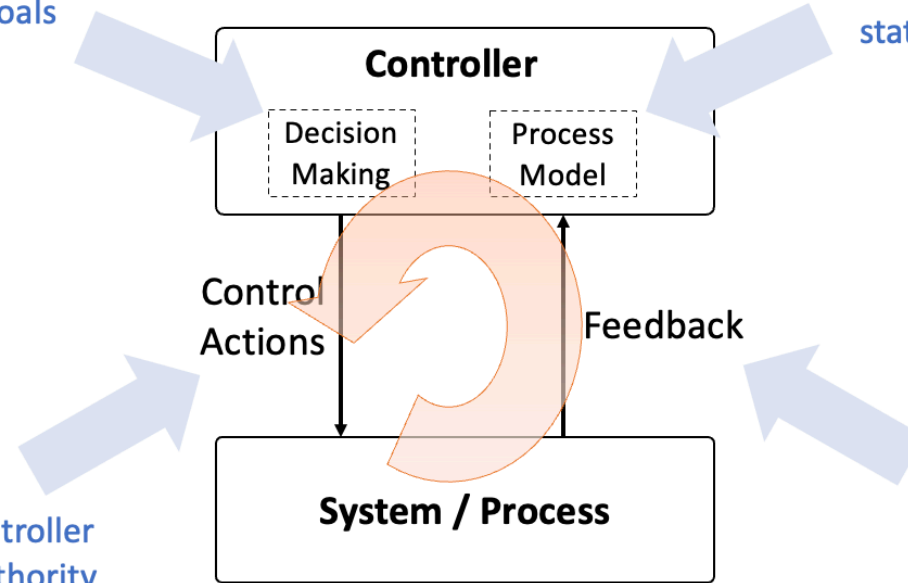
STPA can help anticipate hazardous scenarios caused by:

- Software, computers, and automation
- Human error/confusion
- System design errors
- Flawed assumptions
- Missing design requirements
- Interactions between systems

# Conditions required for effective control and management of safety

**Goal Condition:** The controller must have and prioritize appropriate goals

**Model Condition:** The controller must have a model of the system state and how it can change

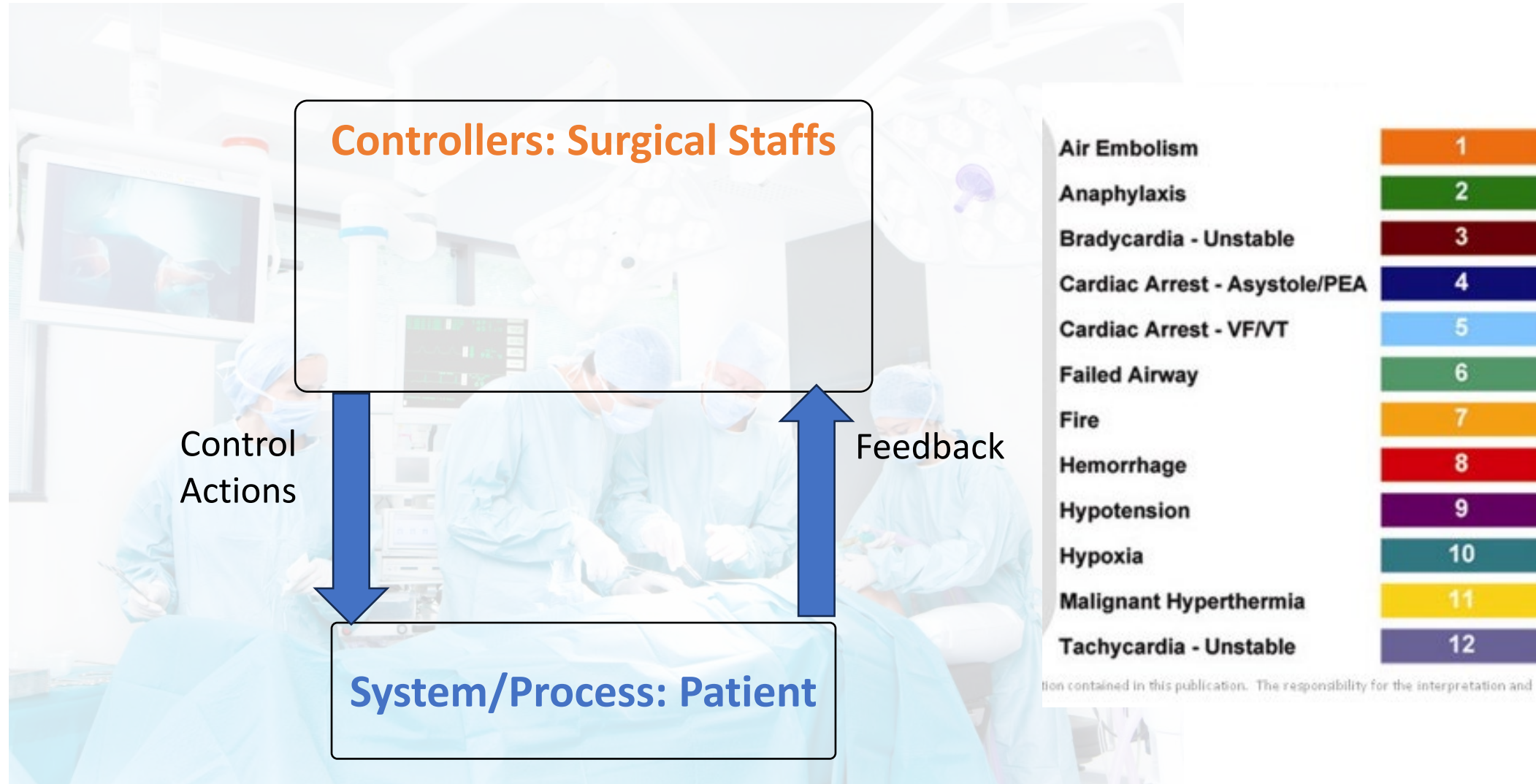


**Action Condition:** The controller must have appropriate authority and control to achieve the goals

**Observability Condition:** The controller must be able to ascertain the state of the system.

Accidents & adverse events often occur because these conditions are broken.

# Crisis in OR from STPA Perspective



## 4: Cardiac Arrest – Asystole/PEA

**Condition:** Non-shockable pulseless cardiac arrest.

**Objective:** Restore pulse, hemodynamic stability.

4

- **Call for help.**
- **CPR** (100 chest compressions/min and 8 breaths per minute)\*
  - Ensure full chest recoil with minimal interruptions.
- **Epinephrine (or Vasopressin).**
- **Check pulse & rhythm** (after every 2 minutes of CPR):
  - If **no pulse and shockable** (VF/VT): **GO TO: Cardiac Arrest - VF/VT Checklist**
  - If **no pulse and NOT shockable** (asystole/PEA):
    - Resume CPR.
    - Read out potential causes (H&Ts).
    - Restart checklist.
  - If **pulse:**
    - Begin post-resuscitation care.
    - Read out potential causes (H & Ts).

### Potential Causes (H&Ts):

- Hypovolemia
- Hypoxia
- Hydrogen ion (acidosis)
- Hypo-/hyperkalemia
- Hypothermia
- Tension Pneumothorax
- Tamponade (Cardiac)
- Toxins (narcotic, local anesthetic, beta blocker, channel blocker)
- Thrombosis (Pulmonary)
- Thrombosis (Coronary)

### During CPR:

- **Airway** ([bag mask ventilation]).
- **Breathing** (100% FiO<sub>2</sub>).
- **Circulation** (confirm adequate IV or IO access) .
  - Consider IV fluids wide open.
- **Assign roles for:** Chest compressions, airway, vascular access, documentation, code cart, time keeping. Orders should be explicitly acknowledged and repeated.

### Drug Doses and Treatments:

**Epinephrine dosing:** 1mg IV, repeats every 3-5 minutes

**Vasopressin 40 Units IV** can be given to replace the first or second dose of epinephrine.

### Hyperkalemia treatment:

- Calcium gluconate (10mg/kg) or Calcium chloride (10mg/kg) IV;
- Sodium bicarbonate 1-2mEq/kg, slow IV push
- Insulin 10 Units regular IV with 1-2 amps D50W (Dextrose 50% in Water)

### Toxin Treatments:

#### Narcotic Overdose:

- Naloxone 0.04 to 0.4 mg IV, may repeat dosing if response inadequate.

#### Local Anesthetic overdose:

##### Intralipid administration:

- 1.5mL/kg IV bolus
- Repeat 1-2 times for persistent asystole
- Start infusion 0.25 to 0.5 mL/kg/min for 30-60 minutes for refractory hypotension

#### Beta-blocker overdose:

- Glucagon (2-4mg IV push)

#### Calcium channel blocker overdose:

- Calcium chloride (1g IV).

\* In patient without an advanced airway: **Cycle of CPR = 30 compressions at a rate of 100/min, followed by two breaths Provide 5 cycles of CPR where "CPR x 2 minutes" is noted**

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# Controlled Process: Patient's cardiac arrest management

**4: Cardiac Arrest – Asystole/PEA** 4

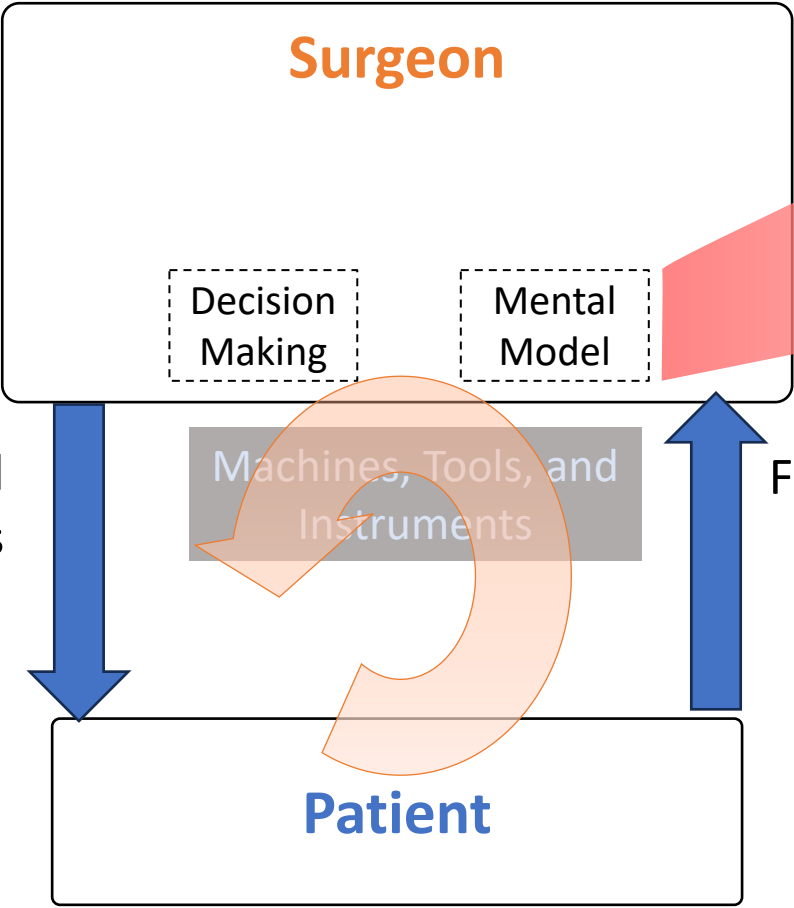
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**Objective:** Restore pulse, hemodynamic stability.

<ul style="list-style-type: none"> <li>• Call for help.</li> <li>• CPR (100 chest compressions/min and 8 breaths per minute)*                             <ul style="list-style-type: none"> <li>- Ensure full chest recoil with minimal interruptions.</li> </ul> </li> <li>• Epinephrine (or Vasopressin).</li> <li>• Check pulse &amp; rhythm (after every 2 minutes of CPR):                             <ul style="list-style-type: none"> <li>- If no pulse and shockable (VF/VT): GO TO Cardiac Arrest - VF/VT Checklist</li> <li>- If no pulse and NOT shockable (asystole/PEA):                                     <ul style="list-style-type: none"> <li>• Resume CPR.</li> <li>• Read out potential causes (H&amp;Ts).</li> <li>• Restart checklist.</li> </ul> </li> <li>- If pulse:                                     <ul style="list-style-type: none"> <li>• Begin post-resuscitation care.</li> <li>• Read out potential causes (H &amp;Ts).</li> </ul> </li> </ul> </li> </ul>	<p><b>Optimal CPR:</b></p> <ul style="list-style-type: none"> <li>• Airway (Use oral ventilator!)</li> <li>• Breathing (100% FiO<sub>2</sub>)</li> <li>• Circulation (confirm adequate IV or IO access)                             <ul style="list-style-type: none"> <li>- Consider IV fluids wide open.</li> </ul> </li> <li>• Assign roles for Chest compressions, airway, vascular access, documentation, code cart, time keeping. Orders should be explicitly acknowledged and repeated.</li> </ul> <p><b>Epinephrine dosing:</b> 1mg IV, repeat every 3-5 minutes</p> <p><b>Vasopressin 40 Units IV</b> can be given to replace the first or second dose of epinephrine.</p> <p><b>Hyperkalemia treatment:</b></p> <ul style="list-style-type: none"> <li>- Calcium gluconate 10mg/kg or Calcium chloride 10mg/kg IV</li> <li>- Sodium bicarbonate 1-2mg/kg slow IV push</li> <li>- Insulin 10 Units regular IV with 1-2 amps 50%W (Decrease 50% in Water)</li> </ul> <p><b>Toxic Treatments:</b></p> <p><b>Neurotic Overdose:</b></p> <ul style="list-style-type: none"> <li>- Fentanyl 0.1 to 0.4 mg IV, may repeat dosing if response inadequate.</li> </ul> <p><b>Local Anesthetic overdose:</b></p> <p><b>Intravital administration:</b></p> <ul style="list-style-type: none"> <li>- 1-2 mg/kg IV bolus</li> <li>- Repeat 1-2 times for persistent asystole</li> <li>- Start infusion 0.25 to 0.5 mg/kg/min for 30-60 minutes for refractory hypotension</li> </ul> <p><b>Beta Blocker overdose:</b></p> <ul style="list-style-type: none"> <li>- Glucagon (1-4mg IV push)</li> <li>- Calcium channel blocker overdose:                             <ul style="list-style-type: none"> <li>- Calcium chloride 1g IV</li> </ul> </li> </ul>
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**Potential Causes (H&Ts):**

- Hypovolemia
- Hypoxia
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- Hypothermia
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\* In patient without an advanced airway: Cycle of CPR - 30 compressions at a rate of 100/min, followed by two breaths Provide 3 cycles of CPR where "CPR x 2 minutes" is noted  
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**Potential Mental Model Flaws:**

1. Believes certain steps are completed
2. Believes chest compressions are effective
3. Believes the team is following the correct protocol

**Control Actions**

1. Initiate CPR
2. Identify and address potential causes (H&Ts)
3. Provide physical assistance and procedural oversight

**Feedback**

1. Patient's physical response to CPR
2. Observations on procedural adherence

**Potential Unsafe Control Actions:**

1. Does not initiate CPR immediately
2. Misidentifies potential causes (H&Ts)

**Potential Inadequate Feedback:**

1. Delayed feedback on patient's physical response to CPR
2. Misleading observations on procedural adherence

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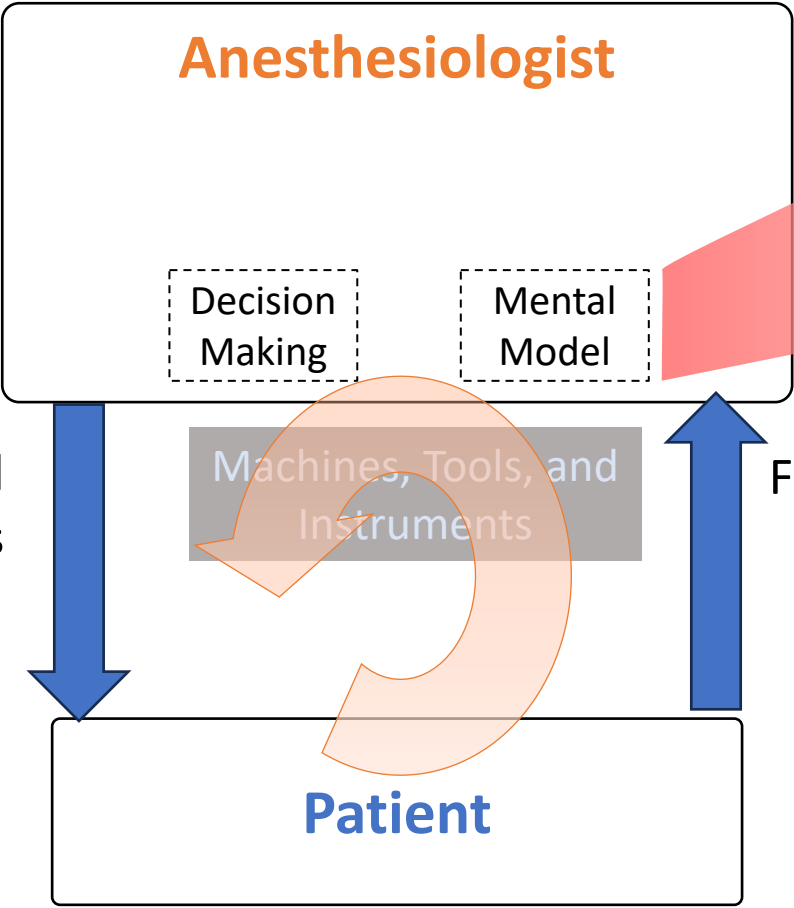
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**Potential Mental Model Flaws:**

1. Believes pulse is stable if no indication otherwise
2. Believes ventilation is adequate if O2 levels are stable

1. Administer epinephrine/vasopressin
2. Monitor drug effects and adjust dosages
3. Manage the airway and ensure adequate ventilation

1. Patient's vitals (pulse, rhythm, O2 saturation)
2. Drug effectiveness (changes in vitals post-administration)

**Potential Unsafe Control Actions:**

1. Anesthesiologist administers epinephrine too late after the onset of cardiac arrest
2. Anesthesiologist does not check pulse and rhythm every two minutes during cardiac arrest
3. Anesthesiologist does not perform defibrillation when the patient is in ventricular fibrillation (VF) or pulseless ventricular tachycardia (VT).

**Potential Inadequate Feedback:**

1. Challenging to know which steps to be done.
2. Not all teams are in the same page.
3. Delayed or incorrect pulse rhythm readings
4. Ineffective CPR feedback (e.g., improper chest compressions not detected)
5. Misleading vitals due to equipment malfunction

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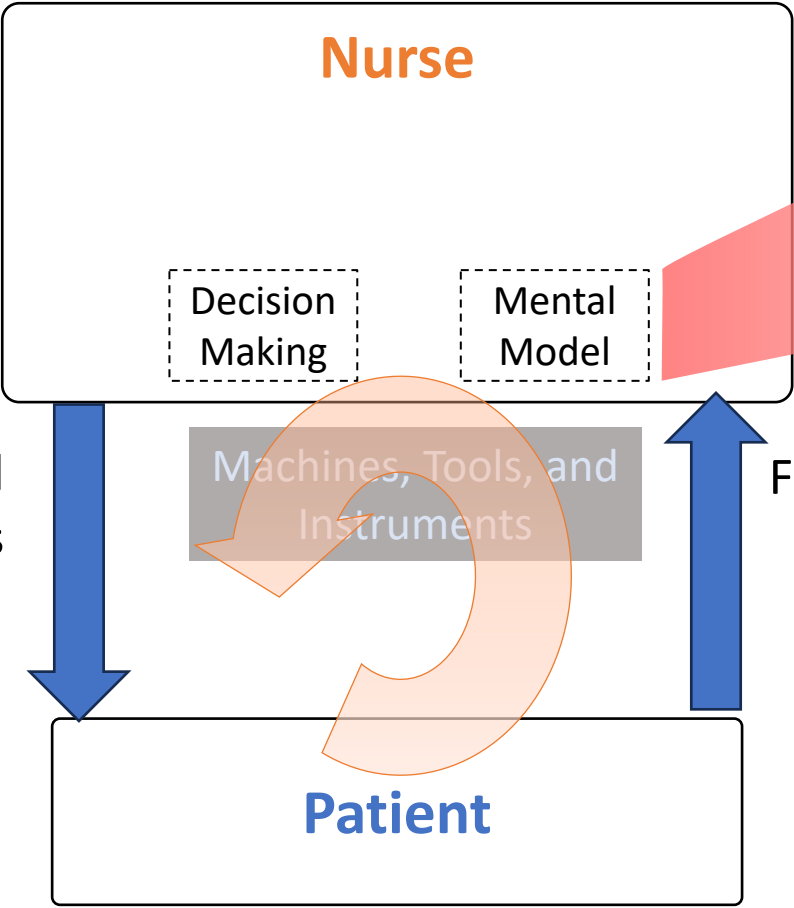
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**Potential Mental Model Flaws:**

1. Believes equipment is operational
2. Believes steps do not need repetition if they appear effective

1. Check pulse and rhythm every 2 minutes
2. Ensure equipment is functioning correctly
3. Support other team members and manage medication inventory

1. Equipment functionality and readiness
2. Real-time feedback from monitoring devices

**Potential Unsafe Control Actions:**

1. Nurse initiates CPR with insufficient chest compression during a cardiac arrest

**Potential Inadequate Feedback:**

1. Ineffective CPR feedback (e.g., improper chest compressions not detected)
2. Delayed or incorrect pulse rhythm readings

# Motivation

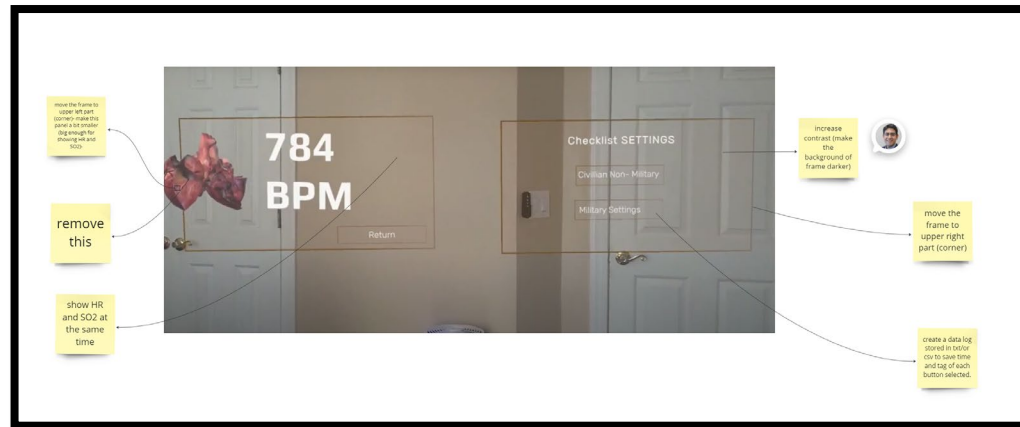
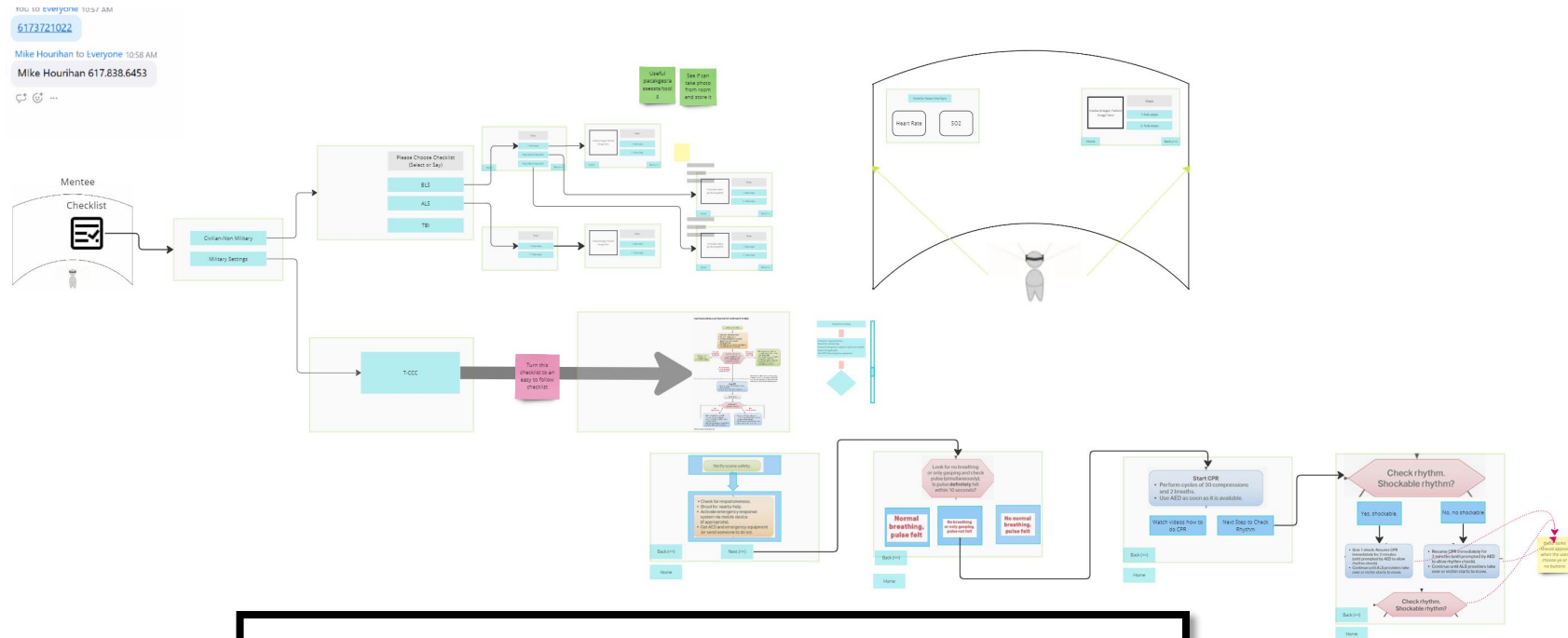


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# AR Checklist Development



# Method: AR Checklist Development



**Unity**



**MRTK**  
MIXED REALITY TOOLKIT



Augmented Reality Group

Paper Checklist Group

No-Checklist (Memory) Group

