

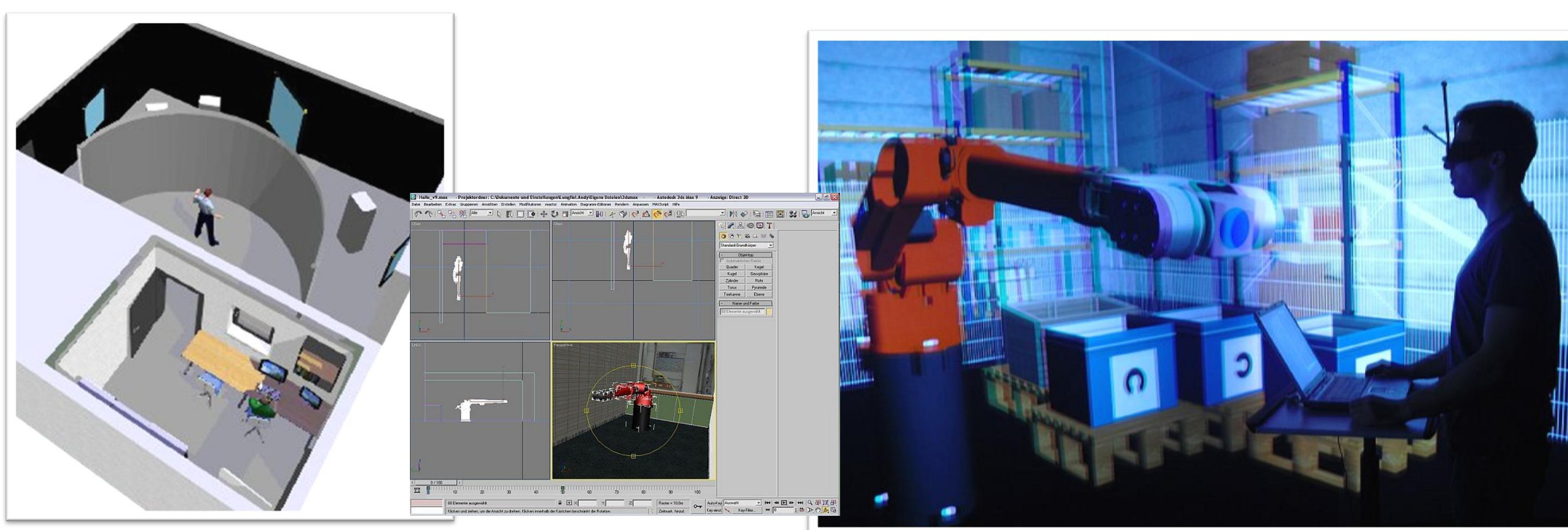
# Requirements for Human-Robot Collaboration

B. Naber, M. Koppenborg, P. Nickel, A. Lungfiel, M. Huelke

## 1. Introduction

- Industrial robots usually operate behind protective fencing. Future industrial workplaces should permit human–robot collaboration (HRC), i.e. spatio-temporal cooperation in a joint movement area.
- HRC workplaces should consider occupational safety and health requirements. Specifications on human factors are pending.
- A research project (ESiMIP) investigated the potential impact of human factors referring to robot speed, distance/proximity, movement predictability.

## 2. Methods



### 2.1 Testing Environment and Tasks

Operators were required to perform manufacturing tasks in an industrial HRC setting simulated in Virtual Reality.

- **Robot interaction task (RIT):** Inspection and control task - robot transports pieces and displays them to the operator.
- **Manufacturing component task (MCT):** Simulation of information processing activities in manufacturing.

### 2.2 Experimental Design

Independent variables:

Investigation A:

- Speed (25 cm/s, 150 cm/s)
- Separation Distance (30 cm, 140 cm)

Investigation B:

- Speed (75 cm/s, 140 cm/s)
- Movement predictability (predictable, unpredictable)

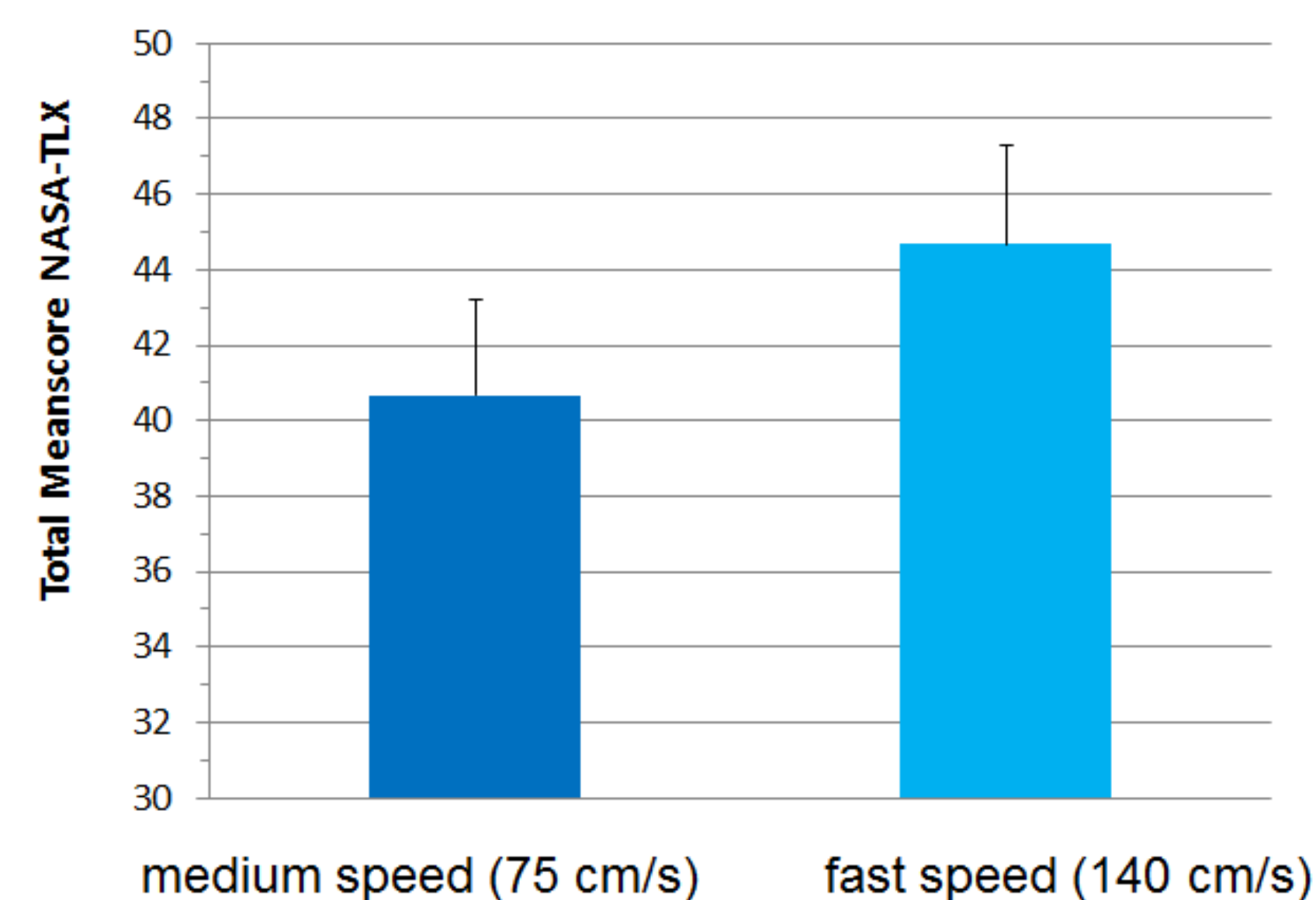
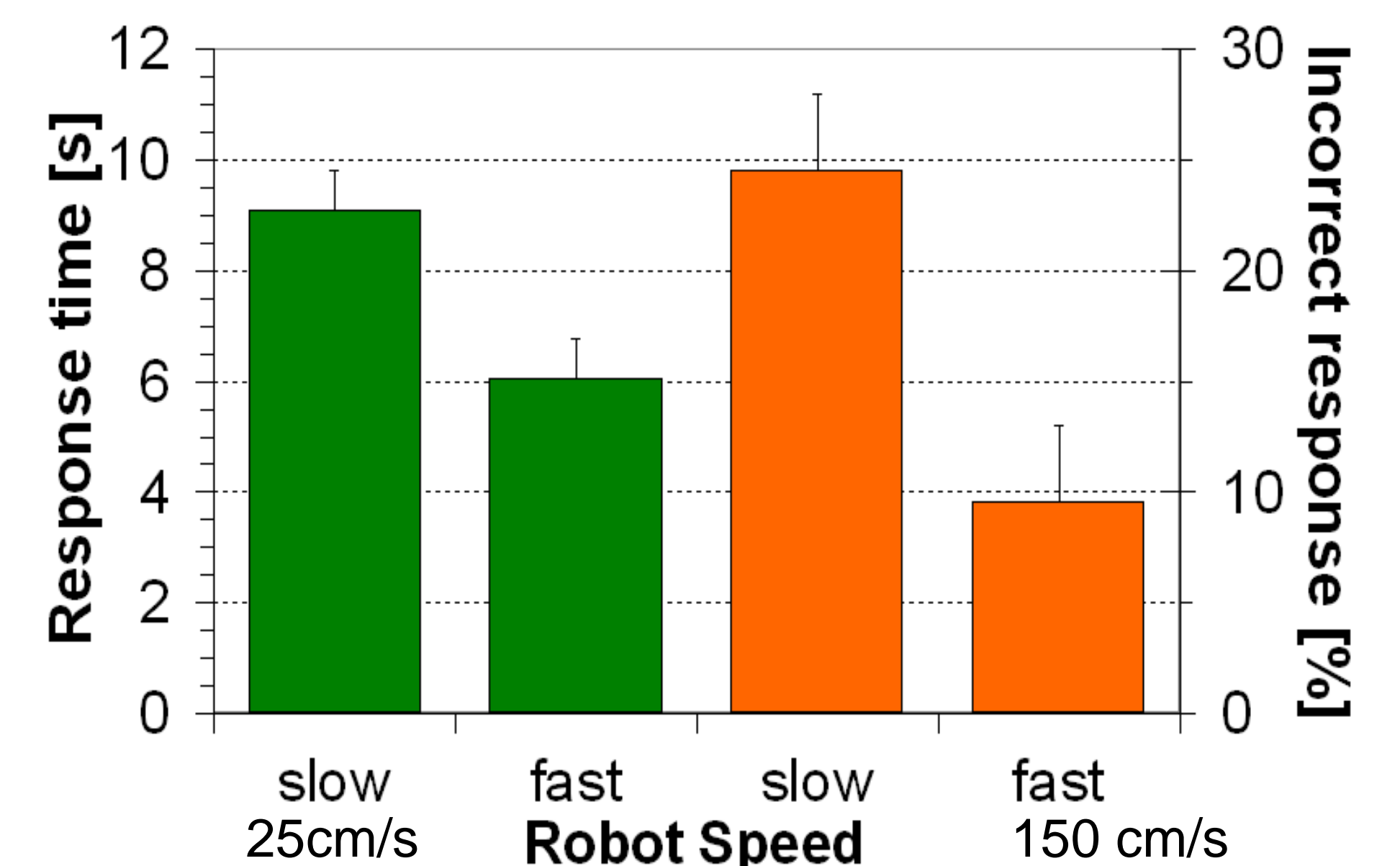
Dependent variables:

- operator performance (response time, error rate)
- workload (subjective assessment, psychophysiology)
  - risk cognition
  - acceptance

## 3. Results and Discussion

Speed:

The participants adapt to high robot speed by working faster and making less incorrect responses.



Fast movements of the robot lead to higher workload and more anxiety.

➔ Operators' performance is best at medium speed.

**Separation Distance:**

A short distance to the robot leads to higher working speed and to more anxiety and a higher risk cognition.

➔ A distance of 30 cm and less should be avoided.

**Movement Predictability:**

In conjunction with unpredictable robot movements, fast robot movements lead to high risk cognition and anxiety.

➔ Robot movements should be predictable for operator.