

## Supplementary Materials

**This document contains supplementary materials for the article “Evoking Emotions in Virtual Reality. Schema Activation via a Freeze-frame Stimulus” published in the Virtual Reality journal**

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### 1. Design of the Study

The study was longitudinal with four iterations and four groups. The main goal of the study was to assess the influence of changes and improvements, both functional and not related to specific functionalities, implemented in a virtual reality (VR) training simulator. Overall, the subjects in the study were randomly divided into three experimental groups and a single control group. The groups differed in terms of experimental manipulation, as different stimuli were embedded into the procedure. The groups were kept consistent through three iterations of the experiment. In the last, fourth iteration, the conditions and types of stimuli were changed.

In the first, second and third iteration of the study, the groups were as follows:

- 1) control - a rescue action in a VR training simulator, without additional stimuli,
- 2) social influence - a rescue action in a VR training simulator with virtual bystanders (male and female virtual agents) present at the scene,
- 3) freeze-frame - a rescue action in a VR training simulator with an emotional, but not interactive element added to the scene (child's toy, child seat or a wedding dress),
- 4) distractor - a rescue action in a VR training simulator with an additional distractor, which did not influence the rescue procedure (a small dog in the first and second iteration and a disruptive, annoying witness in the third iteration).

Belonging to a specific group was kept consistent across these iterations in order to allow longitudinal, within-subject comparisons.

In the fourth iteration actions necessary from the perspective of the *triage* procedure were added. Moreover, the experimental conditions were changed (and therefore the procedure of drawing conditions was done again). This time, the influence of implementing several game mechanics was tested in the following conditions:

- 1) control - a rescue action in a VR training simulator, without additional stimuli,
- 2) time pressure - a rescue action in a VR training simulator; on the VR controller information about remaining time for the task was displayed,
- 3) life bars - a rescue action in a VR training simulator with bars of different colors - green, yellow, red or black - representing the health of the victims visible after classifying the victim according to the *triage* procedure,
- 4) feedback - a rescue action in a VR training simulator with audio and visual feedback after doing an action (victim highlighted in green + a sound representing a correct action or red highlight + “wrong” sound), the participants were also informed on how many correct actions they did after the task.

The experimental task in the first three iterations was to conduct the Medical Rescue Sequence (procedure 2) described in the regulations of the National Firefighting and Rescue System (Zasady organizacji ratownictwa medycznego w Krajowym Systemie Ratowniczo-Gaśniczym 2013). See Figure 3 for the full algorithm. In the fourth iteration, the task was changed to the *triage* procedure (START system; Zasady organizacji ratownictwa medycznego w Krajowym Systemie Ratowniczo-Gaśniczym 2013). See Figure 4 for the *triage* algorithm.

Only the objects relevant from the perspective of the procedure were interactive in the virtual environment. After each iteration, the specific stimuli and the whole virtual environment was improved - new functionalities were added or the visual/audio layers of the environment were changed. For the list of all changes, see Table 1. In the table only functionalities added or modified for the purposes of a specific iteration are given. If there is no information about a feature that was mentioned before, it did not change between iterations.

Table 1. Modifications of the virtual environment across iterations.

| <b>Iteration 1</b> |                      |  |
|--------------------|----------------------|--|
| <b>Condition</b>   | <b>Main stimulus</b> | <b>Specific features</b>   |
| (general)          | -                    | Possible actions: <ul style="list-style-type: none"> <li>- two types of motion (moving at walking speed in a safe space designated using room setup tools provided by the producer of the VR set or moving instantly from one place to another, chosen one using a “teleportation” mode),</li> <li>- moving bollards and the medical bag,</li> <li>- opening the car door, removing the back and side windows,</li> <li>- several interactions with victims (covering with a blanket, checking breath, pain reaction, capillary recurrence and airways, dressing limbs and head, SAMPLE interview).</li> </ul> Sounds: calm background sounds, birds chirping. |
| Social influence   | Bystanders           | Four bystanders (three male, one female) standing on the scene. They do not move and are not interactive.  |

|                    |  |   |
|--------------------|--|---|
| Freeze-frame       | Suggestion of a child's presence on the scene        | A sticker on the back window of the car saying "DZIECKO W AUCIE" ("child in the car"/"baby on board") and a wooden toy train laying on the front passenger seat.  |
| Distractor         | Dog  | A dog standing next to one of the victims (laying woman); barks, wags its tail.   |
| <b>Iteration 2</b> |  |   |
| <b>Condition</b>   | <b>Main stimulus</b>                                 | <b>Specific features</b>  |
| (general)          | -  | Sounds: more adequate volume and content (added wailing and moaning of the victims and sounds of passing cars).<br>Animation: during checking airways victims open their mouths. One of the victims faints 40 s after engaging in an interaction with her.<br>Graphics: improved car model (more details inside and in the trunk, thicker doors). |
| Social influence   | Bystanders   | Increased number of bystanders and grouping them - three bystanders next to each victim (18 bystanders in total). The bystanders gesticulate and follow the participant with their eyes and heads. Seven bystanders are holding smartphones, as if they were recording the event.   |
| Freeze-frame       | Suggestion of a child's presence on the scene        | A car seat placed in the back of the car (visible from the outside of the car wreck). Toy moved to the outside of the car.  |
| Distractor         | Dog  | When the participant does not look at the dog, it follows them (randomly; sometimes follows and sometimes stays in one place). Synchronized video and audio of the dog, added growling noises.  |
| <b>Iteration 3</b> |  |   |
| <b>Condition</b>   | <b>Main stimulus</b>                                 | <b>Specific features</b>  |
| (general)          | -  | Possible actions:<br>- CPR,<br>- checking pulse on radial and carotid artery,<br>- using passive oxygen therapy tools (taken from the medical bag).   |
| Social influence   | Bystanders   | Bystanders are interactive: they can be asked whether they are a doctor (answer is always "no") and to move away (what they always do).   |
| Freeze-frame       | Suggestion of a young woman's (bride-to-be) presence | Changed stimulus: a white dress, resembling a bride's attire, covered in blood placed on the back seat of the car, but visible from the outside.  |
| Distractor         | Disruptive/annoying witness                          | Changed stimulus: an annoying witness, following the participant and commenting the situation at random moments (e.g. "God, are they dead?", "I hope they had insurance."). The annoying witness is not interactive.  |
| <b>Iteration 4</b> |  |   |
| <b>Condition</b>   | <b>Main stimulus</b>                                 | <b>Specific features</b>  |

|               |   |  |
|---------------|---|--|
| (general)     | -   | <p>Possible actions:</p> <ul style="list-style-type: none"> <li>- checking consciousness,</li> <li>- checking if the person can walk,</li> <li>- classifying with green, yellow, red and black bands (bands appear on the wrist of the victim),</li> <li>- street lamp can be checked for electrical voltage,</li> <li>- car can be checked and the battery can be disconnected.</li> </ul> <p>Bollards are already placed on the street (the accident site is secured).</p> |
| Time pressure | Time counter  | A time counter visible on one of the controllers. It shows time remaining until the end of the task and turns red for last 10 s of the task.   |
| Life bars     | Bars representing the health of the victims                                 | After classifying a victim, a green, yellow, red or black bar representing the (changing) health of the victim. Black bar means that the victim is dead.   |
| Feedback      | Feedback during the task (visual and audio) and after it (number of points) | At the beginning of the simulation participant can give a pseudonym for purposes of saving the score; in the end, the total number of collected points are displayed on a dashboard. During interaction with victims audio and visual feedback is given (victim highlighted in green + a sound representing a correct action or red highlight + “wrong” sound).  |

## 2. Framework Plan of the Experimental Procedure

All iterations followed the same framework plan of the experiment. For examples of the setup of the equipment and full algorithms of the procedures used in the study, see Figures 1-4. The framework plan was as follows:

- 1) Welcoming the participant, the participant gives the informed consent.
- 2) Assigning to a condition (*first and fourth iteration*) or identifying the previously assigned condition (*second and third iteration*).
- 3) Preparing the participant for the psychophysiological part of the study (electrodes and sensors).
- 4) Training in using the VR application.
- 5) Physiological baseline (a 8-min relaxing movie viewed in the HMD).
- 6) Instructions for the task.
- 7) Experimental task (5 min).
- 8) Self-report measures collection (~15-20 min).
- 9) (*Only in the fourth iteration*) An additional, 5-min task in VR with conditions as in the previous iterations.
- 10) Taking off the physiological equipment.
- 11) Debriefing.



*Figure 1.* A participant during the experimental task.



*Figure 2.* A participant during the experimental task; an overview of the VR application and physiological signal collecting application is visible on the screens.

## Medical Rescue Sequence

procedure 2

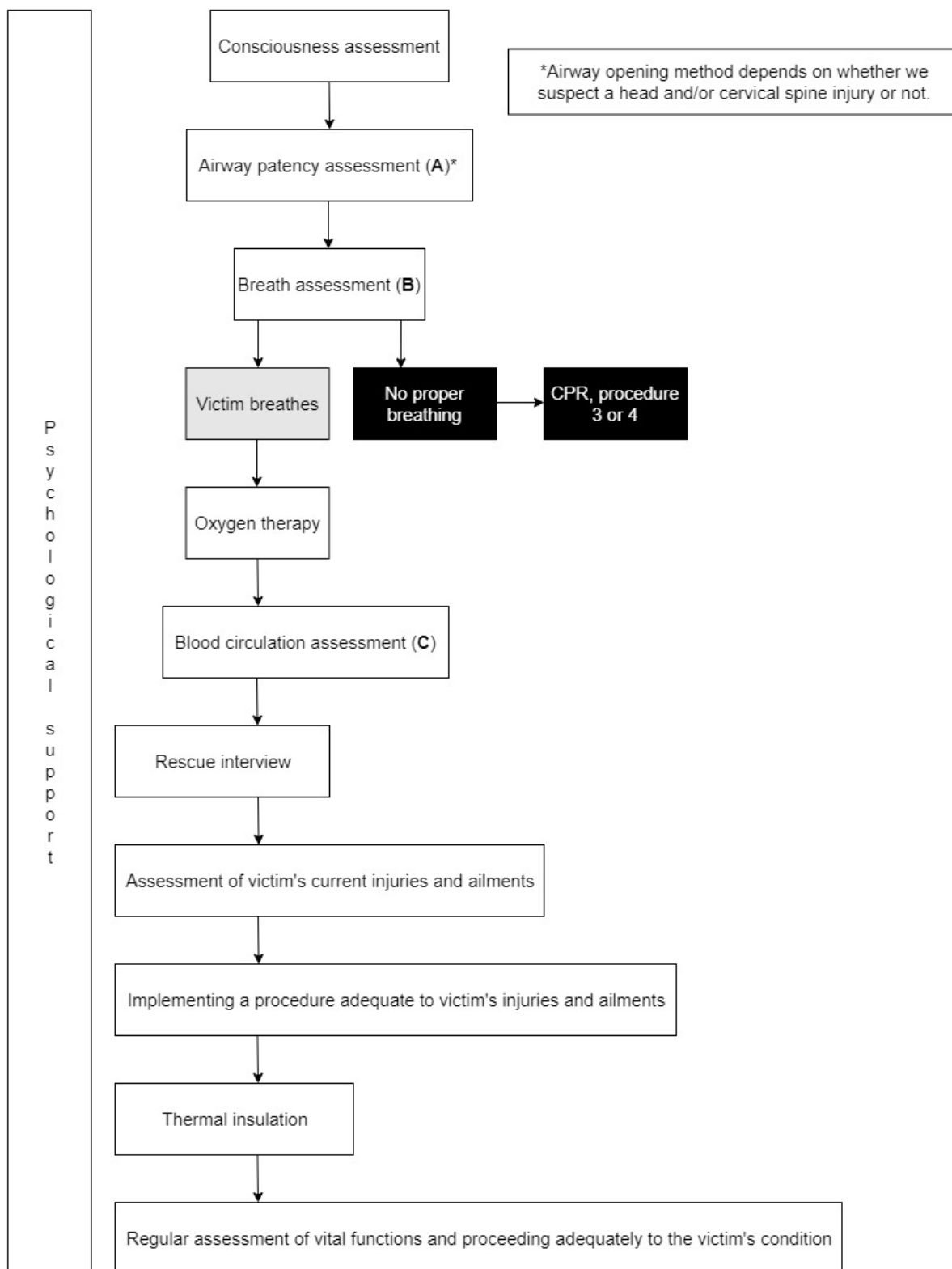


Figure 3. The medical rescue sequence used for the experimental task in the first three iterations of the study.

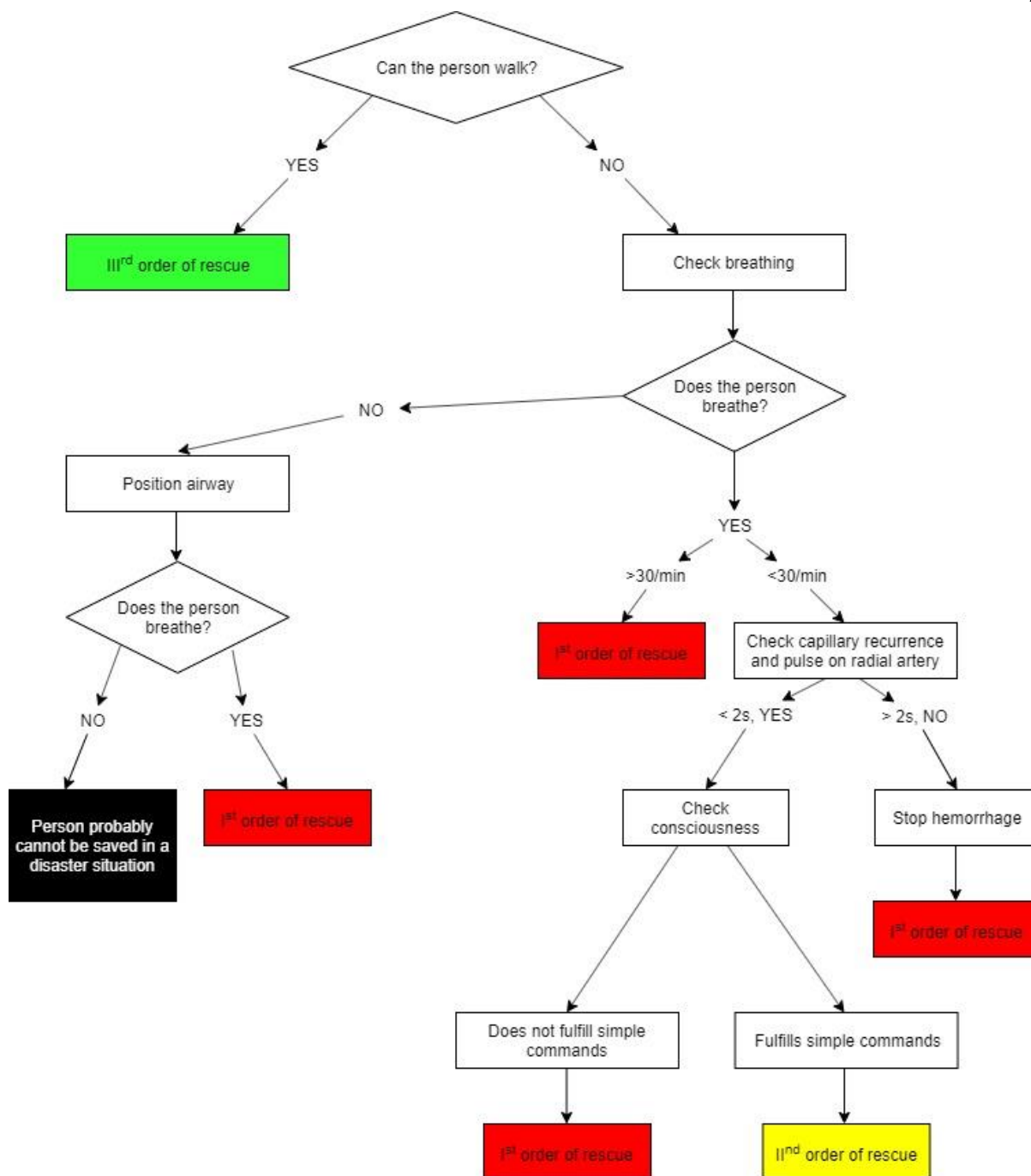


Figure 4. The triage procedure used for the experimental task in the fourth iteration of the study.

### 3. Methods

#### 3.1. Self-report

Several questionnaires were used in order to assess the subjective experiences of the participants during the simulated rescue actions. They were conducted using the tool provided by SurveyMonkey<sup>1</sup> (first iteration) or with a Python script written in PsychoPy (Peirce 2007, 2009). The estimated time needed for completion of all questionnaires was approximately 15-20 minutes. Questionnaires were given in the following order:

<sup>1</sup> [www.surveymonkey.com](http://www.surveymonkey.com)

- 1) a two-dimensional scale for measuring the difficulty of the task and the effort invested in fulfilling the task demands,
- 2) Self-Assessment Manikin (SAM; Bradley and Lang 1994) - a pictorial questionnaire which allows assessment of emotional responses to stimuli in three fundamental dimensions: valence, arousal and dominance,
- 3) Scale of Emotions (SoE, Wojciszke and Baryła 2005) for measuring the intensity of six basic emotions (joy, love, fear, anger, guilt and sadness),
- 4) NASA-Task Load Index (NASA-TLX, Hart and Staveland 1988, Polish adaptation by Zieliński and Biernacki 2010) for measuring subjective task workload,
- 5) the Polish adaptation of the Igroup Presence Questionnaire (IPQ; Schubert, Friedmann and Regenbrecht 2001) by Strojny, Lipp and Strojny (in revision) for measuring the sense of presence (in three dimensions: spatial presence, involvement and realness),
- 6) the Polish translation of the German VR Realism Scale (Poeschl and Doering 2013) to measure the perceived quality of VR graphics (in four dimensions: scene realism, audience behavior, audience appearance, sound realism),
- 7) the Polish translation of the Co-presence Scale (Poeschl and Doering 2015) for measuring social aspects of VR - particularly, engagement in relationships with virtual characters (in four dimensions: presenter's reaction to virtual agents, perceived virtual agents' reaction, impression of interaction possibilities and (co-)presence of other people),
- 8) the Polish translation (Biernacki, Kennedy and Dziuda 2016) of the Simulation Sickness Questionnaire (Kennedy, Lane, Berbaum and Lilienthal 1993) to measure the intensity of simulator sickness symptoms (overall and in three dimensions: nausea, oculomotor and disorientation),
- 9) Scale of Aesthetics (Chevalier, Maury and Fouquereau 2014; Strojny and Strojny 2016) to evaluate the perceived aesthetical aspects of the graphics' quality (in the classical and expressive dimensions),
- 10) Stress Appraisal Questionnaire (SAQ; Włodarczyk and Wrześniewski 2010) to measure situational stress (in four dimensions: harm/loss, challenge-activity, challenge-passivity and threat),
- 11) a manipulation check with questions about the following objects: dog, drone, bystanders, policeman, toy (iterations 1 and 2), annoying witness, wedding dress (iteration 3),
- 12) a sociodemographic survey with questions about: gender, age, height, weight, handedness, total time of work in the fire service. .

### **3.2. Physiology**

In order to assess the participants' effort and engagement, several psychophysiological parameters were measured. The participants' ECG, ICG and EDA was measured using the BIOPAC MP160 system (BIOPAC Systems Inc., Goleta, CA, USA). Electrodes were placed on the right and left clavicle and on the lower left abdomen (for ECG), on both sides of the neck and lower abdomen (for ICG), and on the middle phalanges of the index and middle finger (for EDA).

## **4. Participants**

Due to absence of specific participants or their refusal to participate in the study, the number of participants differed between iterations. The number of participants who took part in each iteration is given in Table 2. During the analyses, some cases had to be excluded due to reasons like missing data or low quality of the



physiological recordings. Therefore, smaller numbers of participants could be used for purpose of specific analyses.

Table 2. The number of participants in the study across iterations.

| <b>Iteration 1</b>         |                                     |                                 |                               |                          |
|----------------------------|-------------------------------------|---------------------------------|-------------------------------|--------------------------|
| <i>N<sub>control</sub></i> | <i>N<sub>social influence</sub></i> | <i>N<sub>freeze-frame</sub></i> | <i>N<sub>distractor</sub></i> | <i>N<sub>total</sub></i> |
| 30                         | 30                                  | 30                              | 31                            | 121                      |
| <b>Iteration 2</b>         |                                     |                                 |                               |                          |
| <i>N<sub>control</sub></i> | <i>N<sub>social influence</sub></i> | <i>N<sub>freeze-frame</sub></i> | <i>N<sub>distractor</sub></i> | <i>N<sub>total</sub></i> |
| 29                         | 28                                  | 26                              | 28                            | 111                      |
| <b>Iteration 3</b>         |                                     |                                 |                               |                          |
| <i>N<sub>control</sub></i> | <i>N<sub>social influence</sub></i> | <i>N<sub>freeze-frame</sub></i> | <i>N<sub>distractor</sub></i> | <i>N<sub>total</sub></i> |
| 25                         | 26                                  | 30                              | 24                            | 105                      |
| <b>Iteration 4</b>         |                                     |                                 |                               |                          |
| <i>N<sub>control</sub></i> | <i>N<sub>time pressure</sub></i>    | <i>N<sub>life bars</sub></i>    | <i>N<sub>feedback</sub></i>   | <i>N<sub>total</sub></i> |
| 26                         | 26                                  | 26                              | 26                            | 104                      |

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