A Text-based Method to Derive the Main Action Structure in Procedural Instructions

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Abstract

This paper presents a text-based three-step approach to identifying the main action structure in multimodal instructions. As a worked example we explore the textual elements in 16 first-aid instructions describing the Heimlich manoeuvre. First, the text is split into clauses, then action clauses and clauses with control information concerning those actions are identified, and finally the actions are categorised with the aim to derive the main action structure for the Heimlich procedure. We discuss methodological considerations and preliminary results for each of these steps. In future research, we will extend this approach to the visual information in multimodal instructions and to other first-aid procedures. Ultimately, this will allow an integrated analysis of the textual and visual elements in multimodal instructions as well as an abstraction and comparison of actions in different first-aid procedures.

1 Introduction and Background

Instructions, for instance those for first-aid procedures, are typically multimodal and take a variety of forms from documents with photos or drawings, to comics, videos, and online apps. To facilitate research on the multimodal design of such instructions, we need a method for identifying the underlying procedure-specific action structure, in which the textual and visual elements presenting the procedural steps can be situated and compared. We propose to use the textual action descriptions as the basis for deriving the main action structure, as many instructions make sparse use of visuals.

Our method starts with a detailed manual analysis, as computational tools for automatic identification and categorisation of actions in instructive texts still have serious limitations (Zhang et al., 2012). To automatically process visual and verbal actions in multimodal instructions, a more detailed investigation of the instructive text accompanying the pictures is indispensable (Chen et al., 2020; Su et al., 2020; Bisk et al., 2020; Li et al., 2019). Such an analysis was attempted for first-aid instructions by Van der Sluis et al. (2018), who used the Alpino parser (Van Noord et al., 2006; Kleiweg and van Noord, 2020) and Cornetto (Vossen et al., 2013), a lexical resource that combines a Dutch Wordnet and a Dutch Reference Lexicon. Van der Sluis et al. (2018) concluded that human intervention is essential to guide an accurate categorisation of the actions.

Deriving a standard main action structure for a procedure from instructional texts requires a good understanding of the actions involved. There is a wide range of choices to describe actions on different levels of abstraction (Steehouder and van der Meij, 2005; Piwek, 2001; Steehouder et al., 2000). For instance, a general description of an action (e.g., check the

breathing of the victim) can be specified by a more detailed explanation of the specific actions to perform (e.g., watch, listen and feel). To support the actions, various types of control information can be added, for example to specify the purpose of an action or the manner in which an action should be performed. By analysing multiple instructions that present the same procedure we aim to derive the main action structure, i.e. the core of a procedural instruction as a sequence of actions that should be performed to reach a particular state. We adopt and expand the annotation model for text and pictures of multimodal instructions developed by Van der Sluis (van der Sluis et al., 2016, 2017).

The research question we aim to answer in this paper is: *How can we describe the main action structure in a set of written instructions that present the same procedure?* We develop a three-step approach and apply it to 16 Dutch instructions on how to perform the Heimlich manoeuvre. Firstly, we divide the texts in the instructions into clauses (Section 3). Secondly, we identify the units that contribute to the action structure by specifying the actions (A) and the control information (CI) (Section 4). Finally, we categorise the identified actions (A) and the situations in which they apply to derive a standardised set of action categories that constitute the main action structure of the Heimlich manoeuvre (Section 5).

2   The Heimlich Manoeuvre Corpus

The corpus of 16 Heimlich manoeuvre instructions we used for our analysis is a subset of the 297 annotated multimodal instructions in the PAT corpus[1]. Examples are presented in Fig-

ures 1, 2 and 3.[2][3][4] The document structure of the instructions is segmented in the PAT corpus in terms of:

- Title: placed at the top of the document with usually a larger font size and different colour in comparison to the main text, presents the content of the document (e.g., Figures 1, 2 and 3).
- Heading: precedes one or more paragraphs and contains information about the content or place of a paragraph within the procedure (e.g., Figure 1 and 3).
- Paragraph: consists of one or more sentences and is separated from the previous paragraph or heading with a hard return or white line. Figures 1, 2 and 3 consist of 3, 7 and 8 paragraphs respectively.
- Picture: photograph (3 in Figure 2), drawing (2 in Figure 1 and 3) or other graphical presentations (e.g., Figure 3).
- Caption: placed above or below a picture often containing a label and/or a description of the content of the picture (e.g., Figures 1 and 2).
- Inset: added textual a/o pictorial elements superimposed or attached to a picture (e.g., Figure 3).
- Extraneous Material: elements unrelated to the instructional content (e.g., page numbers, logos, pictures as in Figure 3).

Three annotators investigated the 16 Heimlich manoeuvre instructions, they thoroughly discussed their findings and iteratively reconciled their analysis. In Sections 3 and 4, the examples used to illustrate the method for analysis are drawn from the PAT corpus.

Figure 1: Example of multimodal Heimlich manoeuvre instruction, MI434; Source: Koffietijd (2017).
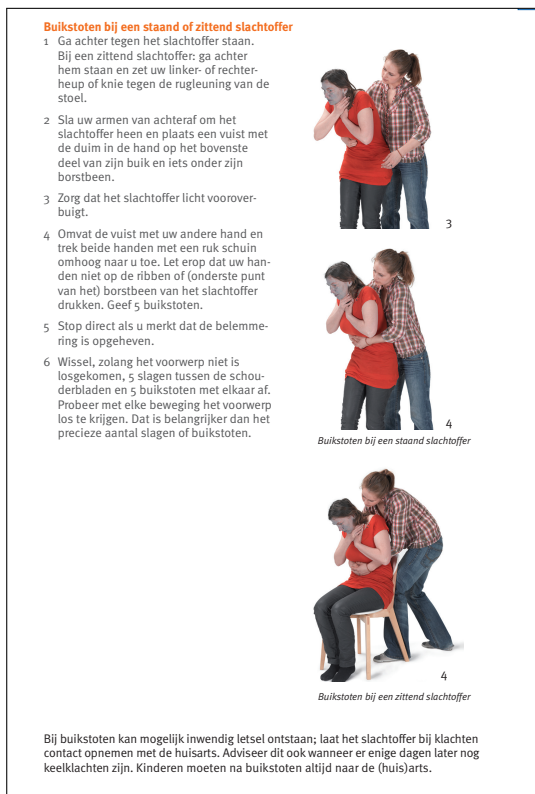
Figure 2: Example of multimodal Heimlich manoeuvre instruction, MI651; Source: Het Oranje Kruisboekje, (2011).
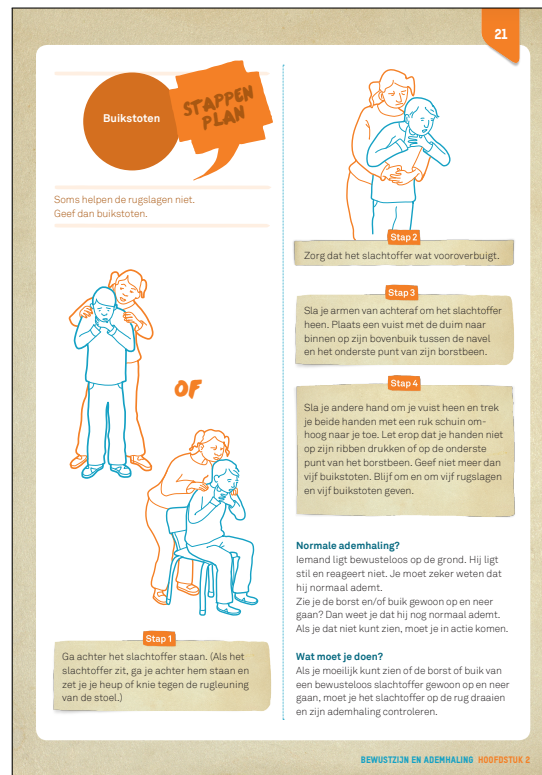
Figure 3: Example of multimodal Heimlich maneuver instruction, MI793; Source: Het Oranje Kruis Jeugdboekje (2017).

3 Determining the Units of Analysis

3.1 Dividing the Text into Clauses

The basis of the analysis are grammatical units in which either an action or control information is described. The units can be full or reduced clauses or stand-alone fragments that serve clause-like functions but that lack the grammatical properties of clauses. Clauses can be subordinate as in 'Als het kind een bril draagt, neem je die af' (*If the child wears glasses, you take them off*; MI486, lines 7-8), or coordinated as in 'Dit doe je met één hand op het achterhoofd van het kind, en één hand op de heup en dan duw je het kind rustig totdat hij weer op zijn rug ligt' (MI486, lines 44-45), which contains two clauses: [*You do this with one hand on the back of the child's head, and*

one hand on the hip] and [*and then you softly push the child until he lies on his back again*]. Clausal constituents (subject or object clauses, complements) were not considered as separate clauses.

3.2 Ambiguities

Sometimes the number of actions in a sentence is ambiguous. Whenever it is not clear whether one or multiple actions are described in a sentence, the sentence is not split into clauses. For example, the Heimlich procedure contains an action in which the helper should pull his fist backwards and upwards while having wrapped both his arms around the victim: 'druk krachtig en snel de vuist in de buik en licht omhoog.' (*press firmly and quickly the fist into the belly and slightly upwards.*; MI432, line 41), and 'Trek je vuist krachtig naar jezelf en naar boven toe' (*pull your fist firmly towards yourself and upwards*; MI425, line 12). Sometimes, this action is not described as one continuous movement, but as consisting of two phases: 'Trek de vuist eerst naar jezelf toe en dan naar boven.' (*Pull the fist first towards yourself and then upwards.*; MI421, line 9). As the verb is elided, this coordinated structure is ambiguous between a clausal or a phrasal coordination. In such cases, the sentence is not split into clauses.

In some cases, parts of complex actions that are described in some of the instructions are left implicit. For example, in 'en plaats een vuist met de duim in de hand op het bovenste deel van zijn buik en iets onder zijn borstbeen' (*and place a fist with the thumb inside the hand on the upper part of the belly and somewhat below the breastbone*; MI451, line 19) the action to make a fist is not explicitly mentioned. In our analysis implied actions are not coded.

Sentences with constructions like 'om .. te' (*in order to*) or 'als dat nodig is' (*when needed*) are split into two clauses. For instance, the sentence 'Kantel het hoofd naar achteren om voor een open luchtweg te zorgen' ([*Tilt the head backwards to make sure that the airway is clear*]; MI493, lines 36-37) is split at the word *to*. Similarly, the sentence 'Schuif eventueel de hand onder de wang van het slachtoffer als dat nodig is' (*Possibly push the hand under the cheek of the victim when needed*; MI493, lines 40-41) is split at the word *when*. However, complements of 'zorg (ervoor) dat' (*make sure to*), 'om te zorgen dat' (*to make sure that*) or similar constructions are not split from their main clause.

4 Identifying Units that Contribute to the Main Action Structure

4.1 Text Organisation

In the documents in our corpus we identified three main parts in the instructional texts: Preamble, Instruction, and Closure. Some documents include a Preamble (e.g., Figure 1), a text preceding the instruction that explains the context in which the instruction is applicable or that provides a summary of the instruction. The core Instruction describes the execution of the procedural actions and the control information to support these actions. Some documents contain a Closure which describes what to do after performing the procedure (See Figure 2). In our study we analysed the core Instruction, excluding the Preamble and Closure.

Within the core Instruction almost all clauses present actions or control information relevant to the described procedure and thus for further analysis. However, we discarded some exceptional clauses: clauses that offer information outside the procedure itself e.g., 'Naderhand moet dus altijd een arts bezocht worden' (*Afterwards a general practitioner must be visited*; MI487, line 16); clauses that describe actions unrelated to the procedure e.g., 'Zie illustratie' (*See Figure*; MI451, line 16); and any organisational text parts such as titles and

subheaders within the instruction like, 'Stap 1' (*Step 1*; MI486, line 3) or 'In 6 stappen van buik naar rug.' (*In 6 steps from belly to back*; MI436, line 1) and 'Als het slachtoffer ligt' (*When the victim lies down*; MI451, line 32).

4.2   Action Clauses

The Action clauses present actions or steps to perform, usually indicated with an action verb in an imperative form.

Examples.   Most Action clauses contain an imperative verb form (second-person in Dutch), usually in clause-initial position: 'Buig de onderarm naar boven' (*Bend the lower arm upwards*; MI420, line 12) and 'Probeer ook het kussen zo neer te leggen' (*Try also to place the pillow in this way*; MI418, line 31). The verb can also appear in other positions, e.g. after a conjunction, as in 'en leg de arm aan jouw kant langs het lichaam,' (*and place the arm on your side along the body*; MI455, line 9). The verb can also be in the infinitive, as in 'Luisteren' (*Listen*; MI435, line 27), which is conjoined with the Action clause 'en voelen naar ademhaling, tenminste 10 seconden.' (*and feel the breathing, at least 10 seconds*; MI435, line 28).

Problematic cases. Not all imperative clauses are Action clauses. Examples of imperative Control Information clauses are: 'Laat de voet van het kind op de grond rusten.' (*Keep the foot of the child on the ground*; MI486, line 20), where the clause describes something that the helper should keep in mind while turning a victim. Similarly, 'Begeleid het slachtoffer tijdens het draaien.' (*Guide the victim during the turn*; MI435, line 17) describes the manner in which the turning action should be performed, and 'Blijf zijn hand tegen zijn wang duwen tijdens het draaien.' (*Keep pressing his hand to his cheek while turning*; MI486, line 25) describes

a continuation of an action during the turning action, and 'door aan zijn zij te trekken' (*by pulling on his side*; MI486, line 23) describes the manner in which to pull a child closer.

Whether a clause is presenting an action or control information is in some cases determined by the context. Whenever a clause describes a repetition of an action that was already introduced, it is categorised as a Control Information clause, e.g., 'Dit mag maximaal 5 keer achter elkaar.' (*This may be done at most 5 times in a row*; MI430, line 67)', where 'Dit' (*This*) refers to an earlier described thrust action. However, in some cases, a repetition of an action is presented as a new action as in 'wissel, zolang het vreemde voorwerp niet is losgekomen, 5 slagen en 5 keer Heimlich-maneuver af;' (*alternate, as long as the strange object has not come free, 5 back slaps and 5 times the Heimlich manoeuvre*; MI451, line 24), which is annotated as an Action clause because it introduces an alternation of (already introduced) abdominal thrusts and back slaps. Note also, that the clause is not split because the two actions in the sentence refer to one overarching action, namely to alternate.

A difficult example is the sentence: 'Je kan dan de kinlift uitvoeren om de ademhaling te controleren' (*You can then perform the chin lift to check the breathing*; MI486, lines 47-48). The conjunction 'om te' does not indicate the purpose of the chin lift action, but introduces the follow-up action. The semantics of the sentence imply that one should first perform a chin lift and subsequently check the breathing. This sentence is split into two Action clauses.

Some clauses have the appearance of an Action clause but actually contain control information. For example, the clause 'Bij kinderen jonger dan één jaar mag je de Heimlich maneuver niet toepassen' (*The Heimlich manoeuvre may not be performed on Children less than one year old*; MI432, line 60) is a warning not

to perform a certain action. Clauses that start with 'zorg dat' or 'zorg ervoor' (*make sure that the legs of the victim are straightened*; MI420, line 10), are marked as control information when no specific action is described.

5 Preliminary Results

5.1 Action Annotation

In total we identified 320 clauses in the Instruction of the sixteen in the Heimlich Maneuver Instructions; 162 Action clauses and 157 Control Information clauses. Table 1 presents seven principal action verb categories that describe the main action structure of the Heimlich procedure: Positioning Helper (N=40), Positioning Victim (N=23), Preparing Thrusts (N=42), Thrust (N=21), After Thrust (N=20), Get Help (N=9) and Resuscitate (N=7). Within the Heimlich manoeuvre corpus all the documents include actions from four of these categories (ie. Positioning Helper, Positioning Victim, Preparing Thrust and Thrust). Actions from the categories After Thrust, Get Help and Resuscitate appear in 12, 2 and 1 document respectively. Some action categories are differentiated in terms of the position of the victim, ie., the thrust action itself and the preparations for it are entirely different dependent on whether the victim is lying down or sitting or standing.

5.2 Situation Annotation

Table 2 presents the situations in which the Action Clauses and Control Information Clauses occurred. The clauses are assigned a Situation code based on an explicit mentioning of the situation in either the Paragraphs or the Headings segments (e.g.,'Als het slachtoffer staat', *if the victim is standing*; MI451, line 16) in the documents. The identified Situations are: Standing or Sitting Victim (N=6), Standing Victim (N=2), Sitting Victim (N=4), Lying Victim (N=7) and Unconscious Victim (N=7).

Every Action clause was assigned at least one Situation code. Some clauses were assigned more than one Situation code. For instance, in 6 documents 10 Action clauses were assigned more than one Situation code, because the described situations in which the victim is unconscious are also assigned the Situation code Lying Victim. The Actions Get Help and Resuscitate do not appear in all Documents as they apply only to Unconscious and Lying Victims. In 4 documents, 5 Action clauses contain a reference to Special Victims i.e. small children or pregnant women. As our immediate goal was the identification of the main action structure for the Heimlich procedure, we left those Action clauses uncoded to avoid distortions.

6 Discussion and Conclusion

To answer our research question *How can we describe the main action structure in a set of written instructions that present the same procedure?* we presented a three-step approach: (1) split the text into clauses, (2) identify the actions that contribute to the main action structure, and (3) categorise the actions. We specified various issues that show that a proper analysis requires a full understanding of the procedure and consideration of the textual context.

We have restricted our analysis here to the identification of action categories, leaving their sequential and hierarchical relations mostly implicit, as our main focus is on providing a representation that supports the comparison of co-referential textual and visual elements.

Note that not all the Action categories occurred in all the documents in our corpus. Arguably, the completeness of an instruction in terms of the actions described will affect the users' understanding and performance. In addition, the distribution of the Action clauses in the documents varied. For example, from the text organisation and the location of the ac-

Table 1: Main action structure of the Heimlich manoeuvre in seven principal action categories, frequencies in number of Action clauses, and corpus examples translated from Dutch.

	Category	Freq.	MI number and Translated Examples
1	**Positioning Helper**	**40**	
1.1	Position behind	15	464 - *Stand behind the client*
1.2	Position hip	1	476 - *Place your hip against him*
1.3	Position forearms	1	476 - *Place your lower arms on the pelvis of the victim*
1.4	Wrap arms around victim	15	421 - *Wrap your arms around the belly*
1.5	Position behind sitting victim	3	451 - *Stand behind the chair*
1.6	Position in case of sitting victim	4	718 - *Place your hip or knee against the back of the chair*
1.7	Position helper lying victim	1	451 - *Kneel with legs spread on top of the victim*
2	**Positioning Victim**	**23**	
2.1	Bend victim forward	14	469 - *Bend the victim forward*
2.2	Position the victim	1	432 - *Let the victim stand or sit on a chair*
2.3	Lay down victim	6	479 - *Place the victim carefully on the ground*
2.4	Turn head sideways	2	432 - *the head turned to the side*
3	**Preparing Thrust**	**42**	
3.1	Make fist	11	442 - *Make a fist*
3.2	Position fist	14	432 - *Place the fist halfway between the navel and the breastbone*
3.3	Grab fist	15	479 - *Take the fist with your other hand*
3.4	Position hand lying victim	2	451 - *Place your hands on top of each other on the upper belly*
4	**Thrust**	**21**	
4.1	Thrust	16	430 - *Now pull your hands (fist) with a jerk, oblique upwards towards yourself*
4.2	Thrust lying victim	2	451 - *Press with the ball of the thumb 3 to 5 times firmly downwards in the direction of the shoulder blades*
4.3	Repeated thrusts	3	421 - *Perform 5 abdominal thrusts*
5	**After Thrust**	**20**	
5.1	Alternate back slaps and thrusts	14	451 - *Alternate, as long as the object is not freed, 5 slaps between the shoulder blades and 5 abdominal trusts*
5.2	Terminate	3	718 *Stop immediately [when the airway obstruction is resolved]*
5.3	Check breathing	1	442 - *then check the victim's breathing*
5.4	Check airway	1	421 - *Check after each thrust if the object is removed*
5.5	Remove objects	1	432 - *Remove any objects and slime from the victim's mouth*
6.	**Get Help**	**9**	430 - *Ensure that professional help is available*
7	**Resuscitate**	**7**	
7.1	Tilt head	1	442 - *Tilt the head carefully backwards*
7.2	Resuscitate	6	442 - *Start the resuscitation of the victim*

Table 2: Frequencies of Heimlich Action types and Control Information in different situations (position and status of victim), and number of documents in which they occurred.

HM A & CI	Sit or Stand	Standing	Sitting	Lying	Unconscious	Unspecified	Documents
Positioning Helper	11	3	8	1	0	17	16
Positioning Victim	4	1	1	3	6	9	16
Preparing Thrust	8	5	2	2	1	25	16
Thrust	4	3	2	2	1	10	16
After Thrust	2	3	2	1	1	12	12
Get Help	0	0	0	5	7	2	7
Resuscitate	0	0	0	5	6	1	6
Total Actions	29	15	15	19	22	76	16
Control Info	26	18	20	8	25	63	16

tion clauses in it, it can be inferred that authors differ in their views on whether the category Get Help belongs to the main action structure of the Heimlich manoeuvre. Although 9 instances of the Get Help Action were identified in the core Instruction, we also found 11 Action clauses instructing to get professional help in the Closure of 8 documents (not included in the analysis presented here).

We plan to further analyse the Action clauses, within which the manner to perform the described action is often specified by the use of adjectives, adverbs and prepositional phrases. These Manner specifications can be broadly categorised as indicating a Position (e.g., 'met je benen wijd', *with your legs spread*; MI451), Direction (e.g., 'naar je toe', *towards yourself*; MI451), Location ('in de buik', *in the belly*; MI432), Distance ('tussen de navel en het borstbeen', *'between the navel and the breastbone'*; MI464), Time ('snel', *quickly*; MI432), Duration ('5', MI421), or something else ('al draaiende', *while turning*, MI476). Similarly, Control Information clauses can be further sub-classified using the categories already identified in the PAT corpus (i.e. Warning, Condition, Purpose, Manner, Advice, Explanation and Situation Sketch).

In addition to the structural analysis presented in this paper, a semantico-pragmatic analysis cf. (Ruppenhofer and Michaelis, 2010) of verbal expressions related to actions and control information with high frequencies may support finding consistent and coherent inferential chains of understanding emergency situations and acting accordingly without going through each step of the instructions.

To examine the role and combination of different modalities, we will extend our model to allow the identification of actions in static and dynamic visuals, starting with the pictures in the Heimlich instructions we analysed in this paper, but also including instruction comics as analysed by (Wildfeuer et al., 2022) and instruction videos.

An important next step in our research will be the application of our method to other procedures in the first-aid domain. As many first-aid procedures involve handling (turning, lifting, bending, etc.) of body parts, we expect a parallel analysis of various procedures to yield important generalisations about action types and their textual and visual presentation.

Presumably, as shown with the translated instructions in this paper, the method we propose and explored in a Dutch dataset will be transferable to similar languages such as English. Future work should show how this pans out for more dissimilar languages (e.g., Japanese), where clauses and action clauses are constructed differently. A parallel analysis of the visual presentations in multimodal instructions is expected to be of great value in such extensions.

The corpus analysis presented in this paper has already been used to inform user studies to test the effectiveness of instructions (van der Sluis et al., to appear). In these user studies experts as well as potential users with no or little background knowledge of the first-aid domain evaluated the pictures in multimodal instructions quite differently. Similarly, the processing and evaluation of the text of multimodal instructions may also depend on the expertise and goals of the user. Ultimately, performance of the procedure of multimodal instructions may be cued or triggered by particular aspects of the presentation. Future research should show how human (or any other rational agents) are tuned to perform a procedure properly. Outcomes of user studies to investigate the effectiveness of instructions will inform the formulation of authoring guidelines to produce effective multimodal instructions.

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