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Learning from language problem related accident information in the process industry: A literature study

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ABSTRACT

Misunderstandings due to language problems are emerging as an underlying causal factor in a wide variety of occupational accidents. Implicated in this are language proficiency and literacy, but also readability of instructions. Coupled to these is the fact that the global workforce holds more migrant workers than ever before, and there are a growing number of multi-lingual shop floor environments, especially in the transportation and health care sectors. The term 'language problem related accident' (LPRA) is proposed here.

This article reviews LPRA trends in industry, especially in the process industry and construction industry. Proposals are made about how to better manage the safety risks associated with LPRAs.

LPRA information was gathered via a literature survey using search-terms related to LPRAs. This search included the governmental resources in Europe, the USA, Australia, several Far East countries, and Africa. Both the information found and the difficulties encountered while gathering this information were analysed and validated by interviews with experts.

Causal information about LPRAs is partial at best: 21 access difficulties are identified. Their resolution will create opportunities for further safety improvement. The main proposals made here relate to public information systems, company safety management, regulatory inspections, accident investigation activities and safety science research.

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1. Introduction

1.1. Discovering language problem related accidents (LPRAs)

Recognition of language problems as a factor of accidents remains unreliable. The investigative process invariably follows the line from identifying the failed element—part, person or organization—to fixing the flaws. However, although language problems have been known about for a long time (Lindhout et al., 2012), they have yet to be included in the checklists and mainstream philosophies of safety investigation (CAIB, 2003). Hence, although accident investigators aim to prevent the same accident from happening again, they tend not to look for or recognise language problems.

There are, however, evident examples of measures to reduce the incidence of LPRA. These include measures such as pictograms on equipment, health and safety signs in factories—such as multilingual warnings on fences around danger zones. Measures to reduce LPRAs are also evident in the form of standards for gestures during hoisting operations. However, these and other attempts to improve communication still fall short because language problems are not well-enough understood.

Language problems are associated with limited proficiency in spoken or written language. In the process industry the main problems are: illiteracy and analphabetism on the shop floor; work instructions that have poor readability, and; workers who lack competence in the language spoken in their workplace. There is also a range of personal medical problems, such as dyslexia, that limit the ability of workers to exchange information verbally or in writing (Lindhout and Ale, 2009).

The present paper contends that the safety risks associated with language problems would be better managed if seen as a distinct safety problem (Farooqui et al., 2007) that is to be found generally throughout industry. At present, these risks are viewed either as marginal outcomes of demographic change and day-to-day communication issues, or as problems that are restricted to particular groups such as foreign workers in dangerous occupations (Farooqui et al., 2007).

As the proportion of migrant workers in the global workforce increases—it is now at its highest (ILO, 2015)—a higher incidence of LPRAs is likely. Learning from language problem related accidents is necessary to generate safety improvement, just as it is for any other accident cause. However, this path seems obstructed for many reasons.

In-depth investigations have identified language problems amongst the causes of major accidents and disasters, including: The 1979 Three Mile Island core meltdown (Kemeny, 1979); the 1977 Tenerife airport disaster (voor de Luchtvaart, 1979; Weick, 1990), the 1986 Space Shuttle Challenger accident (Feynman, 1988); the 1956 Bois du Cazier mine disaster in Marcinelle, Belgium (Urbain et al., 2006), and; the 2005 Texas City BP refinery explosion (CSB, 2007; Baker et al., 2007). As shown in Table 1, all of these cases share language issues among their causal factors. However, as language issues are not identified as a causal category, the issue is not commonly associated with these accidents.

The effects of language issues on industrial safety have been reported for decades. The reports come from a broad spectrum of sectors, for example: construction (Vasquez and Stalnaker, 2004; Corvalan et al., 1994; Janssen, 1973; Hinze, 1966); agriculture (McKay et al., 2006; Bobek et al., 2008; Krenn and Haidinger, 2009; Arcury et al., 2010); marine shipping (Hetherington et al., 2006), and; health care (Taylor-Adams and Vincent, 2000; Herfs and Gishti, 2016). However, until the 1990s, language issues were subsumed within the 'human error' and 'culture 'categories of accident causes. Reason's work on human error (Reason, 1990, 1997) was a turning point, and from the end of the 1990s, language issues started to be considered (Escobedo et al., 2012) as a distinct class of safety problem and as a focus of research(Trajkovski and Loosemore, 2006).

1.2. Differential frequencies in international statistics

Between 2000–2004, researchers in several countries established that foreign workers have higher incident and mortality rates than the indigenous population. Four example, in the German building industry, four times as many foreign workers were victims of 'falling object' accidents, compared to indigenous workers (Arndt et al., 2004; Loh and Richardson, 2004). Similar studies in the U.S. indicated that migrant workers were at greater risk of accidents than other workers (Nash, 2004; Orrenius and Zavodny, 2009; Sanders-Smith, 2007; Vasquez and Stalnaker, 2004; Farooqui et al., 2007).

Researchers started to recognise language issues in the aetiology of accidents affecting foreign workers. In Australia's construction industry, it was revealed that workers simply did not understand the orders given to them, and were showing higher accident rates (Trajkovski and Loosemore, 2006). In 2004, Dutch researchers mentioned language problems as a possible safety risk in the process industry, and recommended that it be further investigated (COT-DHV et al., 2004). In 2007, after their review of migrant worker safety, the European Agency for Safety and Health at Work recommended further research (Vartia-Väänänen et al., 2007). In the same year, language problems were found to cause accidents in the Norwegian construction industry (Ødegård et al., 2007). Furthermore, in the years following, several researchers in the Netherlands focused on shop floor communication with foreign workers (Breedveld et al., 2007; Boege, 2008; Paul, 2010). One result of the research activity in this period was the recognition of language problems as a factor in accidents, but with little light shed on the magnitude and nature of language problems.

Table 1
Some examples of LPRA related disasters and characteristic quotes from the accident investigation reports.

Year	Description	What happened	Death toll	LPRA aspect
August 8, 1956	Marcinelle, Belgium	Mine disaster	262	*"..an Italian worker misunderstood his Wallonian colleague.."* (Urbain et al., 2006)
March 27, 1977	Tenerife, Spain	Airplane collision	583	*"Neither..were certain what this ambiguous phrase meant.."* (Weick, 1990)
March 28, 1979	Three Mile Island	Core meltdown	–	*"..lack of clarity in their operating procedures.."* (Kemeny, 1979)
January 28, 1986	Over the Atlantic, near Florida	Space shuttle Challenger SRB explosion	7	*"..a lot of these guys didn't know how to write good memo's.."* (Feynman, 1988)
March 23, 2005	Texas City	Refinery explosion	15	*"..a verbal miscommunication occurs between operations personnel.."* (Baker et al., 2007)

The main consequence of the research mentioned was, however, to establish that migrant workers, wherever they were working, were generally at disproportionate risk of accidents. Nor is the situation static: in Europe, there is increasing mobility of labour within the EC member states and from outside. This finding has been consolidated by a raft of studies. For example, an investigation of Hong Kong construction worker accidents showed 5.3% of the work-related injuries happened among ethnic minority workers although they are only 2% of the total workforce (Chan et al., 2014). Several studies have found different accident rates between indigenous workers, minority groups and migrant workers (Yee, 2000; Arndt et al., 2004; Bobek et al., 2008; Bust et al., 2008; Shafii et al., 2009; Haslam et al., 2005; Boden and Rees, 2009; COT-DHV et al., 2004; Vasquez and Stalnaker, 2004; Eggerth et al., 2012; Langeland, 2009; O'Connor et al., 2005, 2011).

Moreover, a review by Salminen in 2011 (Salminen, 2011) showed that on average, over a wide range of countries and professions, a foreign worker faces more than twice the injury risk level when compared to native-born workers. The magnitude of this problem can be illustrated with the example of the annual death toll of approximately 1000 foreign born workers in the U.S. (OSHA Occupational Safety and Health Administration, 2017). Half of these lethal injuries would be due to being a foreign worker. In 2018, the relative contribution of language issues and other cultural issues was explored among safety managers in the Norwegian construction industry and were found to be 66 and 44 percent respectively (Wasilkiewicz et al., 2018). In the U.S. example this would mean that some 330 foreign workers die every year because of language problems, mainly the lack of English proficiency.

The evident statistical differences between foreign and indigenous workers can be partly explained by exposure factors, such as working in more dangerous jobs and working longer hours (Guldenmund et al., 2010, 2013). Also, in the construction sector, the agencies which supply low wage labour, within which migrant labour is an increasing proportion, can be reluctant to provide basic safety training to their workers (Rasaki, 2015).

Studies in the current decade, however, have highlighted the significance of language problems to the safety of migrant workers and minority groups. The multilingual shop floor has become an international matter of concern (Lindhout et al., 2012). In 2012, language problems were identified as a major safety problem in the Hong Kong construction industry (Swuste et al., 2012). And language problems were reported as a main causal factor of accidents in the Health Care sector (Taylor-Adams and Vincent, 2000). Furthermore, research in the U.S. and in Norway found that multilingual teams of workers are half as safe as teams in which all workers speak the *lingua franca* (Lankina, 2010; Alsamadani et al., 2013; Flynn, 2014; Flynn et al., 2013).

Although researchers are now focussed on language problems and their safety consequences, research studies are often inconclusive, generating relatively few findings robust enough to allow effective and straightforward measures to be taken. There are a range of reasons, not least the practical difficulties associated with research into safety within this area of the economy. Studies on migrant worker safety have in some cases led to inconclusive results due to small sample sizes, the changing compositions of migrant worker groups, and underreporting (Boden and Rees, 2009). Other studies, which looked at language problems alongside other factors, such as such as cultural differences and differential allocation of dangerous work to foreign workers, did not reach conclusive findings about their relative contributions to accident rates (Farooqui et al., 2007; Orrenius and Zavodny, 2009).

There are also methodological reasons to doubt that language problems are recognised reliably. Accident investigation processes have been criticised (Lundberg et al., 2009) for insensitivity to causal factors that fall outside their yardsticks. Language problems appear to be subject to this selective blindness: investigation processes do not look for them, and do not find them.

The foregoing suggests that language problems are just one of the factors that place migrant workers at greater risk of injury. However, one of the messages of this paper is that language problems are a problem for the workforce in general, affecting not only migrants but also—and in far greater numbers—indigenous workers. The language problems faced by indigenous workers are due mainly to illiteracy and readability, amongst other causes. The authors contend that treating language problems as an identifiable and coherent safety risk will lead to better understanding and accident prevention for the whole workforce.

1.3. The recognition of LPRA in the Netherlands

Over a period of fifty years, public policy in The Netherlands have moved from denial to action on the safety risks associated with migration and with language problems. In the 1960's, migrant workers from Southern Europe and North Africa voiced concern for their safety. Accident statistics in Germany showed these workers to be greater risk. In the Netherlands, however, these statistics were initially refuted by the opinion that these should be compared to accident rates in the workers' country of origin and within the same industrial sectors (Janssen, 1973; Hinze, 1966). In contrast, in 2010, the 2:1 ratio reported earlier was found to hold true in the Netherlands: foreign workers were found to be two times more often the victim of an accident than Dutch workers (van Beek et al., 2010).

Since the early 2000's, language problems have been a recognised, if inconsistently treated, causal factor in official accident statistics. The Labour Inspectorate of the Dutch Ministry of Social Affairs and Employment used to issue annual reports about occupational safety. These reports contained in-depth statistical analyses on causality for given categories of accident. The 2014 issue presented differential frequency analysis about accidents among Dutch and foreign workers; it includes several examples of LPRA

descriptions (Inspectie, 2014). Prior to that, during the period 2003–2009, detailed reports on major accidents in the process industry had been issued mentioning LPRA causality in several cases (Arbeidsinspectie, 2003, 2004; Arbeidsinspectie, 2005, 2006; Arbeidsinspectie, 2007, 2009). However, the Dutch Government's 2015 report about occupational accidents does not explicitly mention LPRAs but kept the differential analysis of the accident frequencies of Dutch and foreign workers (Bellamy and Aneziris, 2015).

Looking at Dutch industry in general, language problem related accidents account for somewhere between 5 and 10% of all reported accidents. In the Dutch high-risk Seveso chemical industry, the accident rate related to language problems was found to be between 5%–10% of the accidents reported (Lindhout and Ale, 2009). In general industry, 53 out of 770 accidents investigated in the Netherlands were found to be explicitly related to insufficient proficiency of the language at work (van Beek et al., 2010). The current official estimate is that 7% of accidents in the Netherlands are related to language problems (Kamer, 2011).

The nature of safety related language problems was explored in 2009 (Lindhout and Ale, 2009). It found ten scenarios specific to LPRA in the Dutch chemical industry. These are summarised in Table 2. The study also found three distinct types of language problem:

- a workers' inability to speak the language needed on the multilingual shop floor;
- a companies issue of written instructions with poor readability, and;
- an illiterate worker who is unable to read and write (Lindhout and Ale, 2009).

Improvement of each of these three problems requires specific measures in specific conditions (Lindhout, 2010; Arbobesluit, 2013; van Guldener and den Besten, 2014). International studies have found these three main LPRA factors to hold true in the construction industry (Roelofs et al., 2011; Escamilla et al., 2017) and in health care (Taylor-Adams and Vincent, 2000; Lankina, 2010). Other studies support the view that these three factors are true of LPRAs across industry in general (Sanders-Smith, 2007; Krenn and Haidinger, 2009).

In the last ten years or so, progress has been made both in attempts to remedy language problems and to study them. Measures to prevent LPRAs have been proposed (Lindhout et al., 2012). In safety management practice, the increasing awareness of LPRA risks resulted in several measures being taken as a precaution, even before the problems and risks were fully investigated (Lindhout et al., 2017).

Preventing LPRA accidents has been the subject of several government initiatives in the Netherlands. These produced guidance documents on practical ways to deal with the first two types of language problem: multilingual shop floor problems and readability improvement (van Guldener and den Besten, 2014; Blom and Leenders, 2011; Brukman et al., 2010). The third type of problem, illiteracy among workers, is being dealt with via the education system, a societal covenant, and an illiteracy prevention foundation (Stichting Lezen and Schrijven, 2018). A programme was started in 2013 to improve communication on multi-lingual shop floors in the metal industry (Paul, 2013). In the same year, proficiency in the *lingua franca* was made mandatory for some professions in the Netherlands (Staatsblad 203, 2013).

Looking back on these developments, it can be concluded that acknowledgement of the emerging language risks to safety have resulted in preventive action to protect workers. In that respect, the system was responsive, but the investment of research into LPRAs lagged behind. The necessity to explore this subject in a broader context in the Netherlands was confirmed by several LPRAs in the Transport sector. Notable amongst these were the 2010 rail-grinding train accident in Stavoren (OVV, 2011) and a lethal shipping accident in 2011 (de Ruyter, 2012). Meanwhile, research continued and more evidence was added to support the general finding that workers who cannot speak the *lingua franca*, the agreed common language in the workplace, are more at risk than other workers (van Beek et al., 2010; van Guldener and den Besten, 2014; Herfs and Gishti, 2016; Griens et al., 2012). By 2017, the prevention of LPRA at work became a new point of attention in the international scientific community, resulting in a newly emerging safety research area: '*language and safety*' (Lindhout et al., 2017). However, progress remains slow relative to the social importance of the problem.

2. Problem definition

The authors have focused on learning from *Language Problem Related Accidents*, LPRAs. An LPRA is potentially a rich source of data, but in practice, much of this is lost through shortcomings in investigation methodology and learning processes (Jacinto et al., 2011). The scale of the language problem—a factor in an estimated 7% of all accidents in Dutch industry (Kamer, 2011)—suggests that research and prevention work is justified. Furthermore, the incidence of LPRAs is likely to increase as the proportion of migrant labour in the workforce increases (ILO, 2015).

The authors examined the question:

> To what extent is information about 'language problem related accidents' (LPRAs) accessible, and how could learning from LPRA information be improved?

3. Method

A sequential accident model (Reniers, 2010) was used to identify the types of information in accident records that would determine language problem related causes.

This required a three-step approach. The first is a review of the literature surrounding LPRAs. The review provided a basis for the second step: an analysis of the accessibility of LPRA information. The third step was to identify proposals for improving learning from LPRAs, and for further research.

3.1. Quality of sources

A meaningful result in the emerging scientific field of 'language and safety' (Lindhout et al., 2017) cannot be achieved if the systematic literature review is limited only to scientific sources. This is because many accidents, including LPRAs, are reported in official governmental public information, non-governmental organisation (NGO) reports, in reports by national and international research institutes, and private company proprietary reports and databases. This so-called 'grey' literature (Wessels, 1997) is currently the best available information from accident investigation practice and is therefore included in this study.

Literature search on the internet via Scopus, Google Scholar, Research Gate, was used to find available LPRA information in a variety of scientific peer-reviewed journals, books and congress papers. 'Grey' sources were searched via Google and Google Scholar.

3.2. Search terms

After an initial search, a set of search terms was composed, reflecting the current use of words and concepts. The following English search terms were used to find both scientific and 'grey' information sources: "Language barrier; occupational accident;

Table 2
LPRA related scenarios in the chemical industry, in order of descending probability.

Nr	Scenario	Description of LPRA contribution to causality
1.	Misunderstanding	Not understanding each other due to language problems
2.	Deviation from instructions	Instruction was not understood (due to: written or verbal instruction not in workers own language, worker illiteracy, readability level not matching worker reading skill level).
3.	Situation unknown	Not grasping knowledge about the workplace, or a potentially important new or incidental situation, and its dangers, from instructions.
4.	Activity not done	A necessary activity was not performed due to not grasping the functional information about what or where to do it, from instructions.
5.	Design not understood	A wrong understanding of the function of the installation due to incomplete or different view on the design.
6.	Habit intrusion	Do something wrong due to lack of understanding of instructions and choose by default for own habit or copying behaviour from previous task.
7.	Danger underestimated	Choose a wrong way to do a task due to not understood, hence underestimated, danger or difference between actual risk and risk perception.
8.	Not used to situation	Mistake due to inexperience, poor ergonomics, not well understood information about the situation.
9.	Insufficient education level	Mistake due to education level being too low to understand explanation of the task at hand.
10.	Violation of rules	Mistake due to deviation of poorly understood rules resulting in more dangerous way to achieve result.

illiteracy; readability; multilingual; causation; example; occupational; accident; language; misunderstanding; anecdotal accident descriptions; migrants; foreign workers; communication problems; learning from accidents; safety".

Within the set of terms, various combinations were used to conduct searches iteratively until no more new relevant sources were found. Finally, the reference listings of these sources were screened to widen the search.

3.3. Inclusion/exclusion

As stated, both scientific and 'grey' sources about accident frequencies, causality and 'anecdotal' descriptions were included. The search was carried out for sources published in the period 2000-2018. A small number of older sources were admitted, as these hold information about the first recognition of LPRAs. Included were any sources written in English or Dutch, originating from Western Europe, the USA, Australia, the Far East and Africa. Source texts were screened for the terms: *multilingual shop floor*, *illiteracy*, *poor readability* in connection with safety or accidents. The three aspects (i.e. multilingual context, readability, and illiteracy) were complemented with several others in the search.

Sources were also screened for: accessibility of information by academics and the general public; whether they present information about reporting and investigation methods; about LPRAs and differential accident frequencies, and; about practical experience with preventive measures. These aspects constitute a *qualification criterion* for sources of LPRA information.

3.4. Sequential LPRA model

Since the 1950s, it has become usual to model accidents as a sequence of events. This started with sequences depicted as domino blocks (Heinrich, 1950). Any accident scenario, including those that kill or wound a worker, would most likely follow the sequence of events depicted in Fig. 1 (Reniers, 2010). Many current models present 'layers of protection' and are commonly used in the process industry, and in other sectors when adapted to fit the context (Burke and Signal, 2010). Ideally, accident investigations deal with how an accident occured and explain why it happened (Abdelhamid and Everett, 2000). Quite exceptionally this was done in 2013 by Cheng and Wu (2013) who studied 354 accidents in the construction sector in Taiwan. They found that, in the period 2000 and 2010, foreign temporary workers were more frequently involved in 'falling object' and 'caught between' accidents. They claimed this to be due to the workers' limited language skills and involvement in more dangerous work. Moreover they provided a frequency distribution of the unsafe acts and unsafe conditions found to precede the accidents involving foreign workers. In order to understand what happened during any reported LPRA, there must be information available on where, when and how the accident took place and, most important of all, what sequence of events preceded it. The circumstances are important too, since they enable potential dangers to become manifest and cause damage and harm. Making these circumstances visible requires an accident investigation method that delves into underlying causation (Katsakiori et al., 2009). Based on a comparison of several frequently used accident investigation methods to determine how these 'reveal' LPRA information (Lindhout, 2010) a sequential accident model was chosen for the present study. In this model a generic sequence of events (Reniers, 2010) is used to specify the kinds of data needed about an LPRA from an accident record or a report. These data need to be sufficient to identify the accident scenario and the underlying language problem that caused the LPRA, see Fig. 1.

In the hypothetical LPRA case shown in Fig. 1, a foreign construction worker does not understand a safety instruction written in Dutch.

A language problem precedes the 'direct' cause in an LPRA scenario, fitting in at the level of a 'process deviation'. Hence, we contend that future prevention relies on in-depth investigation of LPRAs. Whether or not an LPRA scenario can be reconstructed from the accident information constitutes a *criterion for completeness* for LPRA information sources.

3.5. Analysis

The collected literature sources were analysed to identify LPRA information accessibility issues. The analysis used the LBD (Literature Based Discovery) approach (Swanson, 1986). Accessibility issues qualified as a recurring 'phenomenon' in this study if the same accessibility issue, or a one very similar to it, was mentioned in two or more sources. Only accessibility issues that met this 'multiplicity' criterion were included in the analysis. Common recurring issues were extracted from the literature sources, checked against the multiplicity criterion, then grouped and compiled into a list of 'difficulties' (see section 5), in accordance with the guidelines published by the Joanna Briggs Institute (2008).

Next, the clusters, named 'difficulties', were described in a short summary text including references. Also, if the source literature contained improvement suggestions, these were added to the descriptions. Finally, the improvement suggestions were sum-

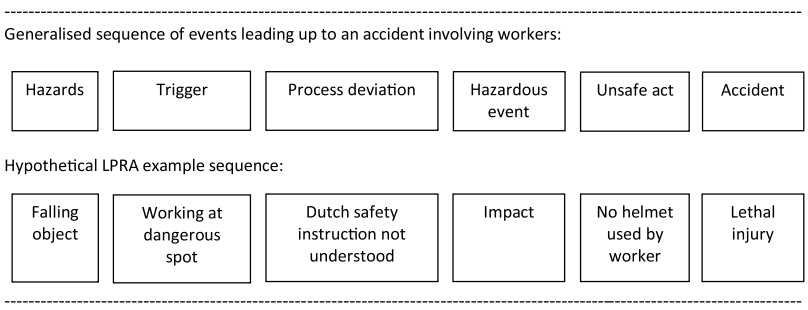

Fig. 1. Generalised sequence of accident events and LPRA example scenario.

marised and presented in terms of the stakeholder best placed to put the improvement in place.

3.6. Interviews

In depth interviews were held to verify the findings from the analysis and to validate the outcome from the perspectives of the safety regulation and safety practice. The interviewees were safety experts, selected for their competence and experience of dealing with accident investigations and reporting on a daily basis in the fields of occupational safety and major accident prevention. The experts were selected from the two most implicated stakeholders: regulatory inspection and company management. These experts have all encountered migrant workers related safety management issues first hand in a range of companies, either in inspection management practice or in company safety management practice.

Migrant workers and their representatives were not included. However, the views of these stakeholders have been voiced in other studies that have been reviewed in the present work. Migrant workers were interviewed in six of these studies (McKay et al., 2006; De Lima and Wright, 2009; Magalhaes et al., 2010; O'Connor et al., 2000; Roelofs et al., 2011; Teo and Goh, 2016) and worker representatives in two (Guldenmund et al., 2010, 2013).

Four experts were interviewed at their respective daily work settings:

- 1 Oct 16, 2017, Project manager, Ministry of social Affairs & Employment, Private office.
- 2 Oct 19, 2017, Managing director, Storage & transport company, Company office.
- 3 Nov 15, 2017, EHS manager, Multinational Chemical Company, Production site office.
- 4 Nov 27, 2017, Specialist Labour & Organisation, Ministry of Social Affairs & Employment, Regional office.

The interviewees participated on a voluntary basis. Their anonymity is protected. The interviews were all held face-to-face between interviewee and interviewer.

Before each interview, the respondent received a concept version of the present paper. They were asked to look at both the preliminary description of the difficulties (see Section 5), and at the first draft of our proposals for resolving them (see Table 5). The purpose of the study was explained in advance in a telephone conversation during the planning of the interviews and was briefly revisited at the beginning of each interview.

Each interview lasted approximately one hour. The respondents were asked to freely express their views on the subject matter. Further depth was achieved using 'open' questions. In this way the interviewer ensured that the following subjects were addressed: the study design; the difficulties identified by the analysis; the proposals for improvement; the role of the regulator, and; the role of private companies. Notes were taken by the interviewer as the basis for a short interview summary written afterwards.

3.7. Verification

The compiled list of difficulties, the improvement proposals and the recommendations for further work were verified via interviews. To this end the findings of this study were presented to four experts. Their feedback, as obtained through the interviews, was used to confront the findings with both company safety management and regulatory inspection practices.

4. Results

4.1. Literature search results

Using the procedure described in the method section, the scientific and grey literature was searched for references to the following aspects of language problem related accidents: (i) causality; (ii) accessibility of language topics; (iii) inclusion in investigation methods; (iv) differential rates of incidents, and; (iv) countermeasures. The search produced a total of 166 sources that mentioned one or more aspects of LPRA (see Table 3). All of these 166 sources were included in this study and are listed in the references.

Only ten sources were found that addressed four or all of the five aspects, and treated them in an integrated way (Al-Bayati and Abudayyeh, 2016; De Lima and Wright, 2009; Escamilla et al., 2017; Feilo, 2016; Lindhout and Ale, 2009; Lindhout, 2010; Lindhout et al., 2017; McKay et al., 2006; Trajkovski and Loosemore, 2006; Vartia-Väänänen et al., 2007). In contrast, the remaining sources dealt with just one aspect (67 sources), two aspects (71 sources) or three aspects (18 sources). This suggests that LPRA information is scattered and fragmented.

Looking at the source completeness criterion, that is, whether or not an LPRA scenario could be reconstructed from information presented, some 38 sources qualified. This underlines that, even though 98 sources contain some form of information about LPRA causality, the information about the actual sequence of events during an LPRA is too superficial to reconstruct the actual scenario in 60 out of 98 sources, or 61%.

The publication rate of scientific and 'grey' material on this subject increased rapidly between 2000 and 2015 and then appears to stabilize. This indicates that the body of knowledge about LPRA, including scientific knowledge, is growing.

4.2. Interview results

In order to strengthen the evidence base for the findings and recommendations, the preliminary results, analysis and proposals were discussed with two government safety specialists and two industry safety experts during in-depth interviews. From the notes taken during these expert interviews, held according to the

Table 3
Literature search results.

(A) Sources and their distribution over time.

Sources	Time period					Total
	<2000	2000-2005	2006-2010	2011-2015	2016-2018	
Scientific	8	20	37	44	22	131
Grey	4	5	13	11	2	35
Total	12	25	50	55	24	166

(B) Sources and distribution of LPRA aspects (multiple aspects per source)

Sources	Mentioned LPRA aspects count					Total
	LPRA Causality	Accessibility problems	Investigation methods	Differential frequencies	Taking measures	
Scientific	81	51	49	42	26	249
Grey	17	7	18	9	7	58
Total	98	58	67	51	33	307

procedure described in the method section, the following points emerged:

- The research in this study and its outcome were wholeheartedly supported by all of the respondents. Moreover, they agreed with all of the 21 difficulties and did not criticize any of the evidence presented.
- Respondents noted that 'harmonizing reporting formats' is important for private companies when sharing and comparing accident information, e.g. on a fixed monthly basis.
- The importance of full anecdotal descriptions of accidents was underlined; the interviewees felt that classification systems obscure an analyst's view of what happened.
- One respondents pointed to a practical problem affecting larger plants: during a shut-down, many foreign worker teams are on site at the same time. The site safety staff are simply not able to accompany and watch all of these teams. Safe work must therefore be dealt with within each team by a dedicated team member who receives the site safety training, held in one or two languages. The dedicated team members in turn instruct their team mates. Hence, a large company's safety performance may rely entirely on foreign workers' fully understanding safety instructions in a language that they don't speak. One of the respondents underlined that, as well as raising awareness among government inspectors, the official registration system of accidents needs to be updated. Specifically, it should facilitate the entry of more specific and more complete accident data. Besides language issues, other new emerging phenomena in the continuously changing world of industrial production need to be accommodated in accident investigations and records over time.

These expert notions were used to improve the preliminary article version that was discussed with them.

5. Analysis

The researchers examined the gathered literature sources for LPRA accessibility issues. This was done, following the guidelines in the method section, by noting down a first issue as encountered in the first source. Each subsequent issue found, in this source or in each following source, was either identified as a new issue or as a repeat of an earlier found issue. For a repeat, one count was added to the tally of an existing issue. New issues are noted on a new position on the list. After completion of this screening for issues a reduction step was used to combine similar issues into one cluster. In this way, 115 *issues* were clustered into 21 *difficulties*. These are presented in Table 4, together with descriptions and associated references.

6. Discussion and recommendations

6.1. Findings

6.1.1. Accessibility

Information about how and why language problem related accidents (LPRA) happen, appears to be hard to find. 21 difficulties are identified in this study. Together they constitute a major obstacle for learning from accidents related to language barriers, worker illiteracy and poor readability of instructions.

Three main issues keep LPRA largely out of sight:

- underreporting, both on a general level and also with respect to specific LPRAs;
- incomplete and superficial data gathering about accidents, and;
- incomplete classification of accident types in reports and records.

In this study we could not accurately quantify a percentage of inaccessible, concealed or missing LPRA information. However, there are several indications that the accessibility is poor:

- occupational accidents in general are 50%–66% underreported (Rosenman et al., 2006; Venema et al., 2007);
- within reported accidents some 75% under-representation of LPRAs is found (Lindhout et al., 2011);
- LPRA causality is described too superficially in 61% of the 98 Sources found (in this study).

Hence, although not all 21 difficulties could be quantified in a similar manner, it seems fair to conclude that by far the largest part of the information needed to learn from LPRAs either does not exist or is inaccessible to safety scientists and company safety analysts.

6.1.2. Improvement

Each of the 21 difficulties presents an opportunity to improve access to LPRA data and to learn how to prevent LPRAs. Looking at the variety of difficulties, we observe that no single countermeasure could resolve all of them; many solutions are needed. Furthermore, in practice these solutions are associated with more than one stakeholder group.

Improvement of learning from LPRAs can also be achieved using new methods and techniques, e.g. 'big data', to do research both on previously inaccessible and new sources (Baker and McCafferty, 2005; Tirunagari et al., 2012; Tirunagari, 2015; Van Dijck, 2016; Moura et al., 2017).

Safety management in companies can make use of both existing and new methods to influence the safety behaviour of workers. For example, employers can introduce existing best practices on

Table 4
The 21 difficulties found when searching for LPRA information.

Nr	Difficulty	Description	References
1	Not present in accident statistics	LPRA anecdotal evidence is not visible in the statistics of the most frequent types of occupational accidents. Only 'direct' causes are mentioned.	(OSHA Occupational Safety and Health Administration, 2016, 2017; Brace et al., 2009; Chan et al., 2014; Cheng and Wu, 2013; Inspectie, 2014; Jørgensen, 2015)
2	Poor awareness of language problems	It took several decades to get clarity about LPRA causation. Training and language barriers were considered at first. Multilingual shop floor, proficiency levels, poor readability and illiteracy emerged later.	(Escobedo et al., 2012; Alsamadani et al., 2013; Bell et al., 2004; Breedveld et al., 2007; Brukman et al., 2010; Cameron et al., 2011; Escobedo et al., 2012; Flynn et al., 2013; Paul, 2013; Sanders-Smith, 2007; Goodrum and Dai, 2005; Guldenmund et al., 2010, 2013; Wah, 2000; Steege et al., 2014; Wong et al., 2004, 2005; Vecchio-Sadus, 2007; Lindhout et al., 2012; Ødegård et al., 2007; Loh and Richardson, 2004; McKay et al., 2006; Lindhout, 2010; Lindhout and Ale, 2009; Salminen, 2011; Flynn et al., 2013; Guldenmund et al., 2013)
3	Poor access to anecdotal evidence	Learning from accidents is often done without the anecdotal evidence or by referencing to other sources.	(Stemn et al., 2018; Brace et al., 2009; Chan et al., 2014; Cheng and Wu, 2013; Farooqui et al., 2007; Hon and Chan, 2013; Loh and Richardson, 2004; Oswald et al., 2015; Roelofs et al., 2011; Hide et al., 2003; Kletz, 2011, 2009; Kletz, 2011; McKay et al., 2006; Hon et al., 2010; Pink et al., 2010; Dainty et al., 2007; Starren et al., 2013; Howell et al., 2002; Meardi et al., 2012; Williams and Chapman, 2007; Bobek et al., 2008; Brace et al., 2009; Bell et al., 2004; Duval-Couetil and Mikulecky, 2011)
4	No in-depth study of LPRA causality	Only general insight or a general term is used. Language problems are only acknowledged but not further described.	(Katsakiori et al., 2009; Rollenhagen et al., 2010; Hallowell et al., 2013; Dahler-Larsen et al., 2016; Hellekjær and Hellekjær, 2015; Hollnagel, 2008; Hale and Borys, 2013; Salleh et al., 2012; Corvalan et al., 1994; Dechy et al., 2012; Cagno et al., 2014; Lauder, 2011; Jørgensen, 2015; Magalhaes et al., 2010; Guldenmund et al., 2013; Steege et al., 2014; Teo and Goh, 2016; Lamm et al., 2017; Landsbergis et al., 2012)
5	'What' is known, but 'Why' is unknown	New phenomena are only slowly integrated. Accident reporting focuses on "what" happened rather than on "why" it happened.	(Kingston-Howlett et al., 2016; Lindhout and Reniers, 2017a; Lindhout and Ale, 2009; Hudson, 2007; Hon et al., 2010; Abdelhamid and Everett, 2000)
6	Known but unreported accidents	Foreign accident victims often reluctant to cooperate with investigation, or they return to their country immediately.	(McKay et al., 2006; Boden and Rees, 2009; Guldenmund et al., 2010, 2013)
7	Under-reporting of accidents	Occupational accidents are significantly underreported not only in general (50-66%) but also specifically those in the LPRA category on top of that (estimated at 75%).	(Rosenman et al., 2006; Azaroff et al., 2002; McKay et al., 2006; Castillo, 2015; van der Schaaf and Kanse, 2004; Venema et al., 2007; Lindhout et al., 2011)
8	Court information not fully published	For juridical reasons, investigation of accidents keeps the resulting information about what happened inaccessible for quite a while (years).	(Lindhout et al., 2014; Hon and Chan, 2013; Haslam et al., 2005; Lindhout et al., 2014)
9	Inspection, monitoring and trending systems lagging behind	Data gathering protocols, statistics and trends-reporting lag behind advances in technology and new insights in causality.	(McKay et al., 2006; Lindhout et al., 2011; McKay et al., 2006; Guldenmund et al., 2010, 2013; Bellamy and Aneziris, 2015)
10	Data collection and records taxonomy incomplete	Incomplete database taxonomy leads to underreporting by both private companies and by public organisations.	(Lindhout et al., 2011; Bellamy et al., 2008; Bellamy and Aneziris, 2015)
11	Accident investigation method classification incomplete	Accident investigators allocate an accident to existing, but ill-fitting, classification. This obscures and distorts new insights into accident causality.	(Lundberg et al., 2009; Underwood and Waterson, 2013a; Lindhout, 2010; Lindhout et al., 2011)
12	Demographic definition differences	Accident data gathering is not structured the same way in all countries. This obscures accident rates and their comparisons.	(McKay et al., 2006; Vartia-Väänänen et al., 2007; Ødegård et al., 2007; Boden and Rees, 2009; van Beek et al., 2010; Brukman et al., 2010; Guldenmund et al., 2010, 2013; Vartia-Väänänen et al., 2007; Jacinto and Aspinwall, 2004)
13	Selected public reports not representative	Public availability of anecdotal information to the general is limited to selected (major) accidents chosen for other reasons than being statistically representative.	(Lindhout, 2010)
14	Superficial information gathering	Accident reports often do not present a substantiated root cause analysis. This has various reasons: lacking expertise, no in-depth investigation, ticking boxes, and poor investigation methods.	(Baker and McCafferty, 2005; Katsakiori et al., 2009)
15	Generally poor learning from accidents	Learning from accidents is problematic and reflects shortcomings in: leadership, recording systems, transparency, openness and proactive approach.	(Le Coze, 2013; Parker et al., 2018; Jacinto et al., 2011; Stemn et al., 2018; Gillman and Pillay, 2018; Moura et al., 2017; Ratilainen, 2016)
16	No evaluation of countermeasures	The effectiveness of preventive countermeasures is not always being evaluated. Ineffective measures leave the risks uncontrolled. Best practices might be affected.	(Dainty et al., 2007; Martinez, 2016; van Guldener and den Besten, 2014; Tutt et al., 2011; Hussain et al., 2018; Paul, 2013; Tutt et al., 2011; Chan et al., 2014)

Table 4 (*Continued*)

Nr	Difficulty	Description	References
17	Hidden within 'human error'	Human error classification is designed without bins (sub-categories) to differentiate language problems.	(Reason, 1990, 1997; Lindhout, 2010; Moura et al., 2017)
18	Lost in general taxonomy bins	Accidents may originate from more than one causal factor. Then it may end up allocated to a general classification such as 'culture', 'communication', 'other' or 'unknown'.	(Pinto et al., 2011; Escamilla et al., 2017; Wasilkiewicz et al., 2016)
19	Avoiding accusations of discrimination	The risk of being accused of discrimination led to employers not addressing language problems explicitly.	(Guldenmund, 2018; Al-Bayati and Abudayyeh, 2016; Inkeles, 2014; Lindhout et al., 2014)
20	Problems kept out of sight by victims	Social taboo and isolation lead to migrant workers not always telling others about accidents they were involved in.	(Lindhout et al., 2012; Eggerth and Flynn, 2010; De Lima and Wright, 2009; Gamil and Abdul Rahman, 2017; Williams and Chapman, 2007; Loosemore et al., 2011; Feilo, 2016; Flynn, 2014; van der Schaaf and Kanse, 2004)
21	Fundamental scientific issues	In practice there will be a gap between systemic accident analysis research and current practice. Also language itself and translations have their shortcomings. People often don't listen long enough to grasp the actual meaning.	(Underwood, 2013; Underwood and Waterson, 2013b; Dahler-Larsen et al., 2016; Hacking, 2002)

Table 5
Proposed improvement areas for learning from LPRAs.

I Systems, Public *Better accessibility of LPRA information* via *public accident information systems* Governmental, NGO, Regulator, Legislation, -Increase awareness -Include in database classification -Include full anecdotal information -Make databases accessible -Harmonize public accident reporting formats -Harmonize demographic definitions -Include in accident statistics (see difficulties 1,2,3,8,10,12,15)	II Systems, Private *Innovation of private company safety management and accident investigation methods* Private companies, Scientific institutions -Increase awareness -Reduce social taboo -Include explicitly in safety management systems -Include explicitly in routine accident reporting -Harmonize company accident reporting formats -Publish accident information -Report full anecdotal accident information -Implement countermeasures (e.g. best practices) -Use new methods (e.g. big-data) (see difficulties 2,3,5,15,16,17,18,19,20)
III Contents, Public *Improvement of depth and quality of LPRA reports and records content* Governmental, NGO, Regulator, Legislation, -Increase awareness -Take up illiteracy and readability -Add to inspection subjects -Monitor nature and frequencies -Improve investigation methods -Improve accident reporting (see difficulties 2,6,7,9,11,14,15,18)	IV Contents, Private *Improvement of learning from LPRA via anecdotal accident causality analysis* Private companies, Scientific institutions -Explore causality -Research anecdotal evidence -Research preventive measures -Improve investigation methods -Use new methods (e.g. 'big data') -Evaluate implemented countermeasures (see difficulties 3,4,11,13,15,16,17,21)

LPRA prevention (Lindhout et al., 2012) and by introduction of new methods such as 'nudges' (Lindhout and Reniers, 2017b).

6.1.3. Recommendations

Better prevention of LPRAs depends on access to better information about their causes. Accordingly, we recommend that stakeholders:

- enlarge the volume of LPRA data they report and record, by reducing under-reporting and increasing the detail of each case;
- increase the content, depth and quality of the LPRA information they create;
- improve the access for accident investigators and scientific researchers to existing information sources.

These improvements affect several areas, emerging firstly from the *public* versus *private* split between the official (e.g. Governmental, NGOs, Regulators, Legislators) and other sectors (e.g. private companies, scientific institutions, etc.). Secondly, separate areas emerge from the *method* versus *data* split between systems (such as methods and systems for investigating, recording, and monitoring accidents) and the data included (what information content is being entered into the systems). These two axes lead to a four-cell scheme, as shown in Table 5. The scheme provides an overview of proposed 'learning from LPRA' improvement opportunities, the respective difficulties, and the identities of the relevant stakeholder groups.

6.2. Limitations

The scientific sources included in this study, available mostly in English and some in Dutch, cover a larger part of the industrialised countries. These sources are assumed to be sufficiently representative of the LPRA field. Possibilities to achieve the same for 'grey' sources are limited however. Reports about local data on LPRAs in 'grey' literature would be available for the larger part only in the local language. The limitation to English and Dutch sources is therefore less representative of countries having other languages.

Limited access of LPRA causality information also implies less visibility for the current study. The results of this study are constrained by accessible sources but might be affected by information in existing but inaccessible sources. The authors consider it unlikely that the 21 difficulties found in this study would be altered by including more of such sources.

This study relied to a large extent on secondary sources, although some expert stakeholders were directly consulted. The

nature of the research reported here is such that the authors consider it unlikely that primary data gathering from other stakeholders could have a significant impact on the outcome of this study.

6.3. Validity and reliability

The findings in this study—the 21 difficulties, and the proposals for improvements—are derived from three different information sources: scientific literature, 'grey' literature and expert interviews. The interviews were held at both regulator and company sites. This *triangulation* approach ensures the validity of the results.

The subject phenomenon looked for in this study – the inaccessibility of LPRA causality – emerges from the literature sources via extracted descriptions of obstacles of different types. Here the reliability is ensured by applying the multiplicity criterion to an issue being mentioned in a source, before considering it for inclusion in the analysis. An example of this is that only very few scientific sources mention time-dependent effects in connection to LPRAs. In fact, only one source (Corvalan et al., 1994), later quoted by one other source (Vartia-Väänänen et al., 2007), reported a five-year period for immigrant workers in Australia to blend in with other workers' average accident rates.

7. Conclusion

This study highlights, via literature review and interviews with safety experts, that a significant part of the information about language problem related accidents (LPRAs) is missing, inaccessible or concealed for a wide variety of reasons. The authors encountered some 21 difficulties while gathering such information. These constitute a major obstacle for learning from LPRAs and their underlying causality.

The astounding incompleteness of such information currently makes 'routine' learning in practice about LPRA near to impossible. This jeopardises safety improvement for over 110 million migrant workers and an even greater number of indigenous workers with low proficiency in their own language. The magnitude of this safety risk in The Netherlands is illustrated by the currently estimate that LPRAs account for 7% of all occupational accidents in industry and in other economic sectors such as health care.

The authors propose a way forward for addressing the difficulties reported. These proposals fall into four main improvement areas: public information systems; private company safety management; inspection, investigation and reporting systems, and; scientific research on causality based information content.

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