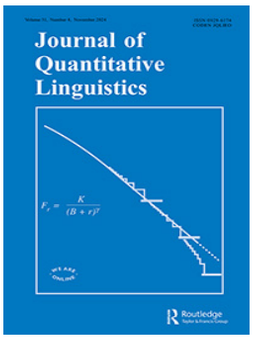

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Reference to Patients in Nurse Shift Handover Meetings: Exploring the Dynamics of Referring Expressions

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ABSTRACT

This paper investigates the dynamics of referring expressions in hospital nurse handover meetings when discussing patients. We apply the methods of the Variable Length Markov Chain (VLMC) and network analyses to model the use of referring expressions and evaluate relationships between them. The models reveal second-order dependencies emerging for metonymy and noun phrases. Specifically, metonymy shows a greater association with the beginning of a reference, particularly in the context of other metonymies. In contrast, noun phrases tend to be more strongly associated with later points in the reference. Further, we introduce the notion of referential typicality, which measures the conformity of sequences of referring expressions to anticipated patterns. We show, for example, that consecutive noun phrases fall outside the typical pattern, whereas metonymical sequences and sequences of pronouns are highly typical. The transitions from metonymy or nouns to pronouns also closely align with a highly typical pattern. Using a Generalized Additive Model (GAM), we then track the overall evolution of referential typicality throughout the duration of handover meetings, from their beginning to end. The study reveals a subtle increase in referential typicality towards the end of these sessions, indicating a trend towards more consistent referencing as the discourse unfolds.

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1. Introduction

Establishing how to refer to people poses a significant communication challenge (Garnham, 2013; Marslen-Wilson et al., 1982). Speakers have many choices about how to refer to people in a given discourse, from highly explicit forms (e.g. proper names) to text-dependent forms (e.g. anaphoric

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pronouns or more creative forms which involve metonymy). The choice of referential strategy is influenced by two conflicting pressures. On the one hand, reference needs to be sufficiently explicit and specific to be identifiable to the listener. On the other, there is a need to communicate efficiently. The effects of these pressures will change over the course of a discourse after a new referent is established or as additional referents are included. For example, using a full name is an effective initial strategy if the person is known to the listener, but using the same name immediately afterwards may increase cognitive load for the listener (the 'repeated name penalty', Gordon et al., 1993, p. 341). Understanding these dynamics is crucial for fostering clear communication. However, to the best of our knowledge, there has been no research to date examining the referring strategies used in real, professional contexts where the effective establishment of reference holds significant consequences – specifically, in the context of information transfer during nurse shift handover meetings.

In this study, we look at the dynamics of reference during nursing shift handover meetings in a medical assessment unit (MAU) where there is a high turnover of patients. The purpose of these face-to-face meetings between an outgoing senior nurse and an incoming team of nurses is to facilitate the secure and efficient transfer of critical information about patients at the start of each new nursing shift and ensure continuity of care and patient safety. Referencing in these sessions is crucial not only for safety reasons but also because it creates an overall cognitive representation of the patients in the mind of nurses, which then may well shape nurses' overall attitude to patients and, in some cases, may inadvertently contribute towards the dehumanization of patients in nurses' perception.

This setting provides an excellent opportunity to study the dynamics of reference, because it encompasses interactions between many active participants and must be completed with extreme efficiency due to the inherent time pressures in the MAU and the high number of unknown patients. Furthermore, critical information about patients needs to be communicated accurately. Failure to do so has real consequences since miscommunication during hospital handover sessions may pose a serious health risk for patients, as shown by few studies that provide a qualitative analysis of the nurse handover meetings (e.g. Bartlett et al., 2020; Lloyd et al., 2021; Novak & Fairchild, 2012; Scott et al., 2012; Smeulers et al., 2014; Spilioti et al., 2019; Ylanne et al., 2021). Historical reports of miscommunication in these meetings prompted the implementation of structured protocols such as Situation, Background, Assessment, Recommendation (SBAR) and Safer Patients Initiative (SPI) aimed at reducing ambiguity and systematizing communication.

Although nurses follow these protocols during handover meetings, one which is designed to standardize the transfer of information and ensure patient safety, the referring strategies used to identify patients are not well

understood. The aim of this study is to analyse the dynamics of reference within this context, addressing the following research questions:

(1) How does reference progress throughout the nurse handover meeting?

(2) What patterns of referring expressions are typical (or atypical) for the studied nurse handover meetings?

We take a quantitative approach to these questions. First, using transcripts of four nurse handover meetings, we identify the strategies used to refer to patients. Within each section of the handovers, we convert every occurrence of a reference to one referent into a reference chain which captures the frequency of transition from one type of reference to another. These chains are then investigated with tools for analysing Markov Chains (MC). This allows us to measure consistency across handover transcripts and calculate the probability of different types of transitions.

This paper provides the foundation for the degree of predictability in referential choice throughout these important meetings. A subsequent paper will explore the relevance of our findings for the healthcare setting and consider whether the recommended templates create the uniformity intended. Recommendations will be considered there for how healthcare professionals can best use referring strategies to uniquely identify patients in their care.

The remainder of the paper is organized as follows. Section 2 gives the contextual framework for the study, and Section 3 introduces the methodology applied in this research. Next, Section 4 features performed analyses, and, in Section 5, we discuss our findings. Section 6 concludes the article.

2. Context

Given the multidisciplinary nature of the work presented in this paper, there are two main research areas that require consideration before we move on to our methods. We will first briefly explore the nature of nurse handover meetings (Subsection 2.1). A description of this special discourse is important since it is unique in many ways. Following this, we will briefly summarize the different referential strategies that might be used to uniquely identify a patient in a nurse handover context (Subsection 2.2).

2.1. Nurse Handover Meetings

To explain the theoretical and methodological approach, it is helpful to give an overview of nursing handover meetings. Within the UK's National Health Service, these are formal sessions where a lead nurse has to refer to the patients in the unit who have varying conditions in a way that will enable the incoming staff to take on their care. At times, patients are referred to

individually (e.g. *bed 1*), at other stages of the handover, they may be clustered together (e.g. *awaiting discharge*).

The four handover sessions that have been analysed in this study were collected and transcribed as part of the preparation for analyses within the context of the whole project.[1] Portions of this data have been previously referenced and partially described in earlier studies (Bartlett et al., 2017; Spilioti et al., 2019). These were recorded in the MAU, which is a 'gateway between Accident and Emergency Unit and more specialized wards' (Bartlett et al., 2017). It is a critical and dynamic unit with a high turnover of patients: within 12 hours, it can provide places for up to 50 patients, often including 20 new admissions. Usually, two senior nurses (i.e. outgoing and incoming), as well as an incoming nursing team (e.g. six nurses, one agency nurse and three health support workers – approximately 12 observers/active listeners, some of whom might not be native speakers) are required to participate in these handover meetings. These meetings last approximately 10–30 minutes.

These meetings are structured by templates (e.g. SBAR or SPI forms). In the four handover sessions under study, the SPI form (see Appendix) was used. This form, completed and read out by the senior outgoing nurse to the incoming nurse team, comprises a list of items that must be addressed during the meeting (Spilioti et al., 2019). Namely, it consists of 22 sections each dedicated to a specific safety briefing topic, starting with the most critical, where danger to life is discussed (e.g. 'Cardiac arrest'[2] and 'NFR'[3]) to less urgent issues, related to housekeeping and organizational matters (e.g. 'Hand Hygiene Audit', and 'Patients returning/VIP'). In addition, the form also has two additional columns; one includes a yes/no tick box for each topic and the other provides a space for comments.

While the SPI form is primarily completed and read out by the senior outgoing nurse, the handover meeting is interactive, allowing the incoming nurses to ask questions and seek clarifications. This dynamic results in each handover meeting serving as a source for multiple reference chains. The features of these chains are explained in the next section.

2.2. Reference Strategies

In this subsection, we cover different types of referring strategies that might be used in a nursing handover context to uniquely identify patients and/or conditions and circumstances. In this paper, we adopt a narrow definition of reference as 'speech act reference' (Hanks, 2019, p. 18): the act of reference that people perform using linguistic expressions. With this view, a referring expression can be perceived as the speaker's linguistic representation of a discourse referent, and this representation can take different forms depending on a variety of factors such as shared knowledge with the addressee, the position of the referring expression in

ongoing discourse and the real-world features of the environment where communication occurs.

One canonical strategy to refer to a person who is known to the listener(s) is to use a proper name. However, the mention of two consecutive proper names hinders linguistic processing – the effect being known as the 'repeated name penalty' (Gordon et al., 1993). Therefore, most discourse incorporates anaphoric devices like personal pronouns to mitigate this effect. Pronouns are typically used more frequently than other forms of reference when their referents have been mentioned recently (Arnold, 2008). Their frequency also increases when referents are not visually salient to the addressee, especially under higher cognitive load (Vogels et al., 2013), and when they refer to a single discourse referent (i.e. as opposed to more than one referent present in the discourse; see Arnold & Griffin, 2007). Although nurses refer to multiple animate referents during handover meetings, we expect to see a high number of pronouns in any given reference chain, because the utterances include discourse referents which are not immediately visually salient, and, predominantly, there is only one discourse referent (individual patient or patient group) described at a time – hence, there is relatively little dispersal of attention, apart from times when a particular patient is mentioned multiple times in various sections of a document or conversation. Finally, in English, pronouns are believed to be used after accessible referents (Allen et al., 2015, p. 142), whereas demonstratives (e.g. *that*) are related to less salient referents (Kaiser & Trueswell, 2011, p. 324).

While the use of pronouns seems to be more dependent on linguistic salience (Vogels et al., 2019, p. 348) – when, for example, the referent is mentioned in a prominent or non-prominent syntactic position (Vogels et al., 2019, p. 339) – zero anaphora is known to mark the most topical entities (Givón, 1983), those for which both the speaker and listener share common knowledge. Therefore, within a sequence of referring expressions addressed to a patient, we expect zero anaphora to be relatively rare, due to the lack of shared information between the speaker and listener. In contrast to zero anaphora, the use of noun phrases as a referring strategy encodes less accessible and the least topical referents (Ariel, 1990; Givón, 1983; Gundel, 1985) – thus, are considered to be stronger referential forms. They are preferred for distant reintroduction and after a topic shift, indicating that, under these circumstances, speakers mostly take into account the listener's position (e.g. Hendriks et al., 2014). Further, the first available lexical noun phrase in an utterance is the most plausible candidate to be linked to a cataphoric pronoun (Cowart & Cairns, 1987). Based on these features of nouns, it is reasonable to infer that, during handover meetings, noun phrases constitute a preferable choice in a sequence of referring expressions.

Unlike nouns, which identify referents directly, metonymic reference relies on associative relations, whereby properties associated with a referent

stand in for the person (e.g. ***Trolley three*** *in MAU is John Smith*). It is commonly perceived as an efficient referring strategy, operating like a shortcut (Fontaine et al., 2023, p. 217). In the context of nurse handover meetings, it can be one of the safest options since it allows for a quick identification of patients through, for example, familiar spatial references (LOCATION for PERSON metonymy), and it is thus not surprising that metonymy appears frequently in our data set.

In brief then, our study examines the interaction between various types of referring expressions and the dynamics that emerge from their interplay in real-world communicative contexts and how the usage of referring expressions changes over time.

3. Methods

Given the considerations highlighted above, in this study we use empirical data from a real context (Subsection 2.2) where we code each referring expression by type (Subsection 3.1) within a reference chain (Subsection 3.2). We then take a probabilistic approach to the analysis using Markov Chain tools Subsection 3.3–3.6) to validate the trends we observed.

3.1. Data Source

The data for this study have been elicited from four nurse handover meetings from a MAU in a Welsh hospital following full ethical approval from the hospital trust and Cardiff University. The nursing shift in this unit lasts 12 hours, and handover meetings are held at 7 am and 7 pm (Bartlett et al., 2017). In our sample, three handover sessions occurred at 7pm, and one at 7am. The recorded sessions were transcribed for the previous studies (Bartlett et al., 2017) and during transcription, all personal, confidential information was removed in compliance with the study's research ethics protocol (for example, the first name and the last name were replaced by [FNLN], followed by F or M to signify female or male patient: i.e. [FNLNF] and [FNLNM], respectively). Informal pre-handover small talk was removed from the analysis because it was not relevant to the current investigation (see Table 1 for more information on data).

3.2. Coding Referential Types

Instances of reference to one patient (if the focus of reference is a specific patient) or to multiple patients (if a group of patients is referred to) were identified and classified in the data. To identify general patterns of referencing during VLMC modelling, we have used the coarse annotation scheme

given in Table 1, which includes seven types of referring expressions. We also explored how the typicality of referring expressions progresses throughout the meetings, and, for this purpose, we applied a more fine-grained annotation. With this fine-grained annotation scheme, eight more referential types have been distinguished: plural noun phrases (annotated as '*n.pl*'; e.g. *five patients*); phrases used with a definite article, instead of a possessive pronoun ('*d*'; there's a lady in (.) A4 [. . .]I did explain to* ***the family***); phrases with no deictic determiners ('*d0*'; ***Heels*** *are intact*); proper names used with an indefinite article ('*f(!)*'; *a Mr [FNLNF]*); demonstrative pronouns ('*dm'; Is* ***this*** *the lady?*); LOCATION for PERSON metonymy that names patients with their respective hospital location ('*lm'; Trolley three in MAU is [FNLNM]*); TREATMENT for PERSON metonymy that identifies patients with their treatment plans ('*tm'; Is that the one that was just coming through the door?* ***the dialysis?*** *. . . oh yeh that one*); CONDITION for PERSON metonymy that refers to patients with their conditions ('*cm*'; *we've had* ***20 admissions***); and post-copular metonymy—i.e. metonymical expression used after the copular verbs *to have* and *to be* ('*pm*'; *we've had* ***a fall***).

3.3. Identifying Reference Chains

In each section of the SPI form, we encountered scenarios featuring either one reference chain or multiple-reference chains, depending on the amount of communicated information. Each sequence of referring expressions in the data constitutes a *reference chain* which is a succession of referring expressions used to refer to a discourse referent – in our study, this can be one patient or a group of patients. For example, the following expressions in bold form reference chains, with the first referring to an individual patient (1) and the second referring to a group of patients (2).

(1) *ur:r* ***trolley 12*** *then (.)* ***she****'s got a grade 2 (.) to* ***her sacrum****.*
(2) ***2 people*** *were diagnosed with sepsis and* ***they*** *had appropriate response.*

Therefore, each reference chain has only one referent. The first expression in the chain represents the first mention of the referent in the discourse and marks the onset of the reference chain. In examples (1) and (2), *trolley 12* and *two people* represent the first mention. The final referring expression in a given chain serves as the marker for breaks between chains.[5] In the examples above, *her sacrum* and *they* are the final referring expressions that denote the referents of a female patient in trolley 12 and two people diagnosed with sepsis, respectively. Moreover, every chain begins with the 'start' (s) state and reaches its conclusion at the 'end' (e) state.[6]

Table 1. The types of referring expressions categorized under coarse annotation.

No	RE	Label	Definition	Example	Frequency			
					H1	H2	H3	H4
1	Noun phrase	*n*	when used in subject or object roles within clauses with reference to a person but not to their attributes, possessions or relations	*gentleman on trolley 3 [FNLNM] (session 2); or trying to get **this gentleman** home*	11	13	30	18
2	Descriptive noun phrase	*d*	Noun phrases that denote attributes, possessions or relations of a referent, together with a determiner (e.g. *the/a, his/her/their*); complex reference	*He won't put **his hearing aids** in so you got to like (.)[4] use your voice to him*	4	21	10	24
3	Proper name	*f*	specific names used to identify a particular patient; all names in the transcripts were replaced with the abbreviation of the 'first name' and 'last name' [FNLN], followed by F or M to signify female or male patient: i.e. [FNLNF] and [FNLNF], respectively	*[FNLNF] is a young girl with pharyngitis*	12	19	12	21
4	Omitted RE: zero anaphora	*z*	a reference position that is filled with a morphologically unrealised form	*49 patients on the ward (.) we've got 5 expected, **3** by ambulance*	1	2	4	4
5	Figurative expression	*i*	fixed expressions that convey meaning beyond their literal interpretation	*she was sat on the floor (.) bewildered (.) apologising (.) **poor thing** (.) but she's fine.*	1	0	0	0
6	Pronoun	*p*	Personal and demonstrative pronouns	***she** was sat on the floor. Is **this** the lady?*	38	156	93	138
7	Metonymy	*m*	Substitution of a referred entity by a concept closely associated with it	***trolley one** in MAU is [FNLNF]*	28	35	29	41

Another important assumption we make is related to whether referencing to the absence of a patient should be considered an instance of reference (i.e. referring expression with the determiner 'no'). With the reasoning that mentioning a patient's absence within a particular group of patients with specific traits is a reference to that group,[7] we have chosen to integrate the instances of reference with the determiner 'no' into our analysis. Because of these formal assumptions, it is possible for a chain to comprise only one referring expression.[8] With these criteria and using the coarse annotation scheme, the examples of reference chains in (1) and (2) can be annotated as follows:

(1) *s, m, p, d, e.*
(2) *s, n, p, e.*

With the fine-grained annotation, these examples are encoded as follows:

(1) *s, lm, p, d, e.*
(2) *s, n.pl, p, e.*

These reference chains were then coalesced into *hyper-chains* containing all reference chains for one handover meeting. As a result, we have four hyper-chains to analyse, each representing reference dynamics within a handover meeting. Table 2 provides information on the number of hyper-chains, chains and referential types in each chain.

In order to establish general reference trends in all the handover meetings, the four hyper-chains were combined in one, composite chain (labelled as 'H_Overall'). This unification allows for establishing reference dynamics for the whole dataset. Additionally, by comparing the composite chain to the individual session chains, we can more effectively assess how well the overall model, based on the composite chain, captures the underlying data. This comparison allows us to evaluate the extent to which the transitions observed in each session align with and are represented in the overall model, providing insights

Table 2. The frequency information on chains and hyper-chains.

Hyper-chain	Number of chains	Overall number of referential types		Number of words in handover meetings	Length of the recording (in min.)
		coarse	fine-grained		
H1	18	7	12	≈2,196	9:25
H2	26	6	10	≈7,445	32:10
H3	23	6	12	≈5,156	27:15
H4	33	6	12	≈3,592	29:39

into the model's generalizability and consistency across different sessions.

Although the sample sizes, presented in Table 2, are small due to ethical considerations, we believe they still effectively capture the main referential trends in the session. Future exploration with larger samples would be valuable in validating the results obtained from this study.

3.4. Analysing Reference Chains with Markov Models

Markov Chains (MC) have been attested on a range of problems. Famously, Shannon (1948, pp. 385–389) applied higher-order MC modelling to the sequence of English letters, showing that, with this methodology, it is possible to produce texts that resemble the English language.

We have chosen MCs to explore the development of reference to patients for several reasons. First, different MC models are known for their simplicity, versatility, and accuracy of prediction (e.g. Sarukkai, 2000). Second, in linguistics, speech and natural language processing (NLP) have also benefited from different types of higher-order hidden Markov chain modelling, for example, in creating models for language acquisition which predict a word given previous word(s) (e.g. Saffran et al., 1996) and for lexical category disambiguation (e.g. Corley & Crocker, 1996). However, to the best of our knowledge, they have never been used to study linguistic reference: the application of MCs to this context has potential to unveil novel insights about referring expressions. As this study explores the dynamics of referring expressions in a given discourse, MCs can help us understand how the likelihood of an expression is influenced by its current context. MCs also analyse trends and patterns in sequences, which is useful in understanding how reference evolves over time.

As a type of mathematical model, MCs follow a rule called the Markov property. This means that what will happen next in the process only depends on what is happening right now and not on anything that happened before (Ibe, 2013, p. 49). That is, in simple MCs, a future state depends only on the current state, which is known as a first-order dependence. If there is a dependence of a future state on a past state, the system displays properties of a second-order MC (Ibe, 2013). Hence, in an n-order MC, the Markov property is defined as the independence of a future state from the n-order past states.

However, a higher-order representation may not be appropriate for every part of a chain. Variable Length Markov Chains (VLMC, Bühlmann & Wyner, 1999; Mäechler, 2019) are an extension of the traditional MC model where the order or memory length of the chain is allowed to vary on a finite space. VLMC is suitable for categorical time series and is based on the tree-structured context algorithm that

determines transition probabilities not only on the current state but also considering the 'context'. A context represents a specific arrangement of states, which includes the current state and the preceding states that contribute to determining the transition probabilities. As a result, the VLMC algorithm grows a large tree with leaves (reflecting the number of unique states in the model). This tree captures the conditional probabilities for different sequences of states at various lengths and may become prone to overfitting. To address this, the algorithm also performs 'pruning' to simplify the tree while retaining its predictive power (Mäechler & Bühlmann, 2012, p. 7). As will be illustrated below, VLMC has a greater predictive power than ordinary higher-order Markov chain models.[9]

To use a VLMC on our data, we define the following initial conditions. We consider each handover meeting (H) to be a sample of reference chains m. We assume that reference chains in each handover meeting develop at times $= 0, 1, 2, \ldots$. For all $n > 0$, X_n is a random variable with a value from 1 to 6 in a set of S of non-negative integers $\{1, \ldots 6\}$ in handover meetings 2 to 4 and with a value from 1 to 7 in a set of S of non-negative integers $\{1, \ldots 7\}$ in handover meeting 1 (based on the coarse annotation; Table 1). Therefore, $\{X_n, n > 0\}$ is a discrete-time stochastic process with a state space S, where each state within the state space corresponds to a specific type of referring expression observed during handover meetings.

In this study, we applied VLMC using the R package 'VLMC' (Mäechler, 2019). The validation of the Markov property in hyper-chains was done with the help of the R package 'markovchain' (Spedicato et al., 2016). We also used this package to experimentally fit higher-order Markov models (Ching et al., 2013).

3.5. Typicality

To compare chains against each other, we present a novel measure of typicality based on the average likelihood of the transitions in a chain compared to the probabilities in the overall data. Not only does this quantify the predictability of the chain, but it also reflects its typicality within a specific context. This is because a greater likelihood of occurrence is indicative of phenomena that are more representative or typical in that particular context. Thus, a highly typical chain will show a more predictable pattern in how it progresses from one state to another. On the other hand, an atypical chain will contain transitions which are less predictable. An average transition probability of a reference chain (ATP) was calculated with the following formula:

$$ATP = \frac{1}{n-1}\sum_{i=1}^{N}\hat{p}_{ij},$$

where $p_{ij} = P\{X_{n+1} = j | X_n = i\}\big(= p_{ij}(n)\big)$. Hence, the average transition probability of a reference chain is the sum of its probabilities of transitions from one state to another, divided by the total number of transitions[10] in that chain. One of the major advantages of ATP is that it is a standardized measure that allows us to compare sequences with varying lengths. This is useful because the studied reference chains have different numbers of transitions, making direct comparisons challenging. After calculating typicality values, we grouped them into three quantiles: low, medium, and high.

We were also interested to explore what factors have an impact on chain typicality. Our focus was to determine how the length of a chain and its placement within a handover meeting influence chain typicality. Since our data show some higher-order non-linearity, we have chosen the method of Generalized Additive Models (GAMs) for regression analysis. GAMs (Hastie & Tibshirani, 1990) are extensions of generalized linear models, which constitute a flexible modelling framework allowing for a mixture of parametric assumptions and non-parametric components. GAMs analysis was applied using the R packages 'mgcv' (Wood, 2011).

3.6. Graph Centrality Analytics

In discourse, some referring strategies facilitate the use of others (e.g. the use of a proper noun may be necessary before using a pronoun). To analyse this feature, we used graph analytics, including such measures as *degree*, *closeness*, *betweenness*, *eigenvector* and *information centrality*. If we imagine the Markov chain as a graph (nodes are strategies, edges are transitions between strategies), then *degree centrality* measures the number of adjacent nodes for each node in the network: the higher the number, the more influential the node is. However, this score reflects only the local information about the node, without evaluating the context of the whole graph (Mester et al., 2021, p. 2). *Closeness centrality*, on the other hand, calculates the shortest path from a node to other nodes and gives weight to the node based on the closeness criterion. It is also viewed as a measure of how easily the information passes from a node to others (Mester et al., 2021, p. 3). Further, *betweenness centrality* quantifies the degree to which a node lies on the shortest paths between pairs of other nodes in the network, and this parameter compensates for the deficiencies of degree and closeness centrality (Mester et al., 2021, p. 3). The score of the *eigenvector centrality* is 'a measure of how important the node is in

the context of the entire graph' (Desagulier, 2017, pp. 286–287). It assigns a higher weight to nodes connected to important nodes. Finally, *information centrality* is a hybrid measure which relates the above-discussed centrality measures, and it is believed that nodes with higher information centrality have greater control over the flow of information within a network (Butts, 2023, p. 118). The calculation and visualization of centrality scores was performed in RStudio (R Core Team, 2022), using the packages 'igraph' (Csardi & Nepusz, 2006) and 'sna' (Butts, 2023).

4. Results

In this section, we present the results of our analyses. We start our examination with an overview of Markov Chains analyses, augmenting our understanding of the identified patterns in reference sequences with graph centrality measures analytics (Section 3.6). Consequently, we introduce the findings derived from analysing the typicality of referring expressions within handover meetings (Section 4.1).

4.1. The Development of Reference as a VLMC Process

To establish the suitability of the MC methodology for our dataset, we began our analysis with the verification of the Markov property within each hyper-chain (using a coarse annotation). We observed that the Markov property, depending on the hyper-chain, emerges at the second or third order: namely, the second order emerges for the reference chains in H1, H3, and H4, and the third for those in H2 and H_Overall. The verification of the Markov property in the hyper-chains suggests that there is extra information that could be modelled. We first tried the method of higher-order Markov chain for categorical sequences (Ching et al., 2013), but the fitted models demonstrated a low predictive power, and, in the transition matrices for the highest order, we observed transitions which do not occur in the real data. The imprecision of the ordinary higher-order MC models, based on the assumption of homogeneity, indicates the non-homogeneous nature of our data—i.e. the transition probabilities between states change over time – and that there is an inner structure within reference chains.

The method of VLMC (Mächler, 2019; Mächler & Bühlmann, 2012), on the other hand, does not have an assumption of homogeneity, and, upon applying this method to our data, we achieve a better fit to the data (Table 3): VLMC effectively identifies and represents the underlying structure of the data.[11]

These VLMC models demonstrate reasonable predictive prowess, as evidenced by their relatively high coefficients of determination, ranging from 65% to 75%. This indicates that a substantial portion of the variability in the

Table 3. Validation metrics for the fitted VLMC models.

VLMC Models	R^2 %	*MC order*	*Leaves No*	*Contexts No*
H1	67.94	2	5	7
H2	75.2	2	8	10
H3	64.7	2	5	7
H4	67	2	8	10
H_Overall	68	2	11	14

data is effectively captured and explained by the models. The remaining unexplained portion can be attributed to the idiosyncrasies inherent in the use of reference by individual speakers.

In light of models' dependencies, captured by contexts, we observe second-order complexity stemming from the transitions between metonymy and metonymy (H1, H2, and H4), a start node and metonymy (H2 and H3), and metonymy and a pronoun (H4). This means that metonymy is most likely to occur at the beginning of reference and tends to be followed by another metonymy or a pronoun. In addition to the above-mentioned dependencies, new ones emerge in the composite chain (H_Overall) which includes dependencies between a noun phrase and a pronoun, and a pronoun and a pronoun. This observation suggests that, as the dataset size increases, the likelihood of observing instances where a pronoun follows a noun phrase and where two pronouns occur together becomes more pronounced.

Simulations of referential sequences with the fitted VLMC models demonstrate the robustness of these models: they predict the dynamics of transitions from one referring expression to another and capture the main dependencies between them. While not all the models can be generalized to fit the data for other models, there are instances where certain models, such as the first, second, third and overall ones, capture similar dependencies (e.g. sequences of metonymy). These results bring us to an important observation about the homogeneity of the composite chain. While the overall model does capture the transitions observed in individual sessions, the current method does not allow us to draw definitive conclusions regarding potential disruptions in data homogeneity, present in individual sessions. This limitation highlights an area for improvement, which could be addressed in future research.

The robustness of the overall VLMC model is shown by the heatmaps in Figure 1: the overall VLMC model effectively captures the dynamics of referring expressions. Nevertheless, the VLMC model exhibits slight discrepancies. It tends to underestimate certain lower-frequency transitions, including those from zero anaphora to zero anaphora and from a start node to a proper name.

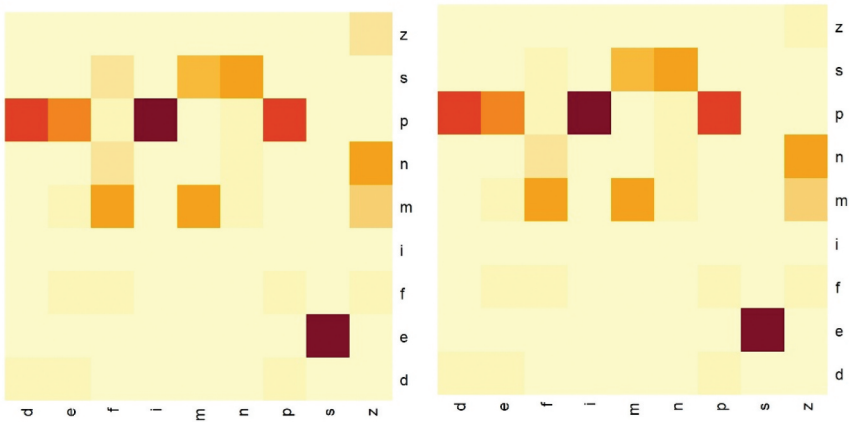

Figure 1. Heatmaps contrasting the empirical sequence derived from the composite chain (left) with its simulated counterpart generated based on the corresponding VLMC model (right). Lighter colours indicate less frequent transitions, and letters indicate the type of referring expression.

As shown in Figure 2, reference to patients tends to begin with metonymy, a noun phrase or a proper name. Subsequently, reference predominantly evolves through the use of pronouns, descriptive noun phrases, figurative expressions and zero anaphora, marking the second distinct stage in the progression of reference cohesion. The transition diagram in Figure 2 captures two types of reference chains found in our analyses:

(i) A patient-centric reference chain that encapsulates comprehensive information about one or more patients. This chain is initiated with an identifying mention of the patient(s), followed by a series of referring expressions that contribute to a detailed characterization of the referent(s).
(ii) A location-oriented reference chain that serves to identify the spatial context of the patients. This chain typically manifests as a sequence of metonymic expressions.

Among all referential types, pronouns have the highest values of degree centrality which implies the local importance of pronouns for such nodes as descriptive complex noun phrase, proper name, zero anaphora and figurative expression. Pronouns play a mediating role by frequently occurring within this specific environment, serving as a bridge that connects these referential types. They also have the highest values of eigenvector centrality, which conveys their significance not only at the local level but also on the scale of the whole graph. However, pronouns do not have the highest closeness

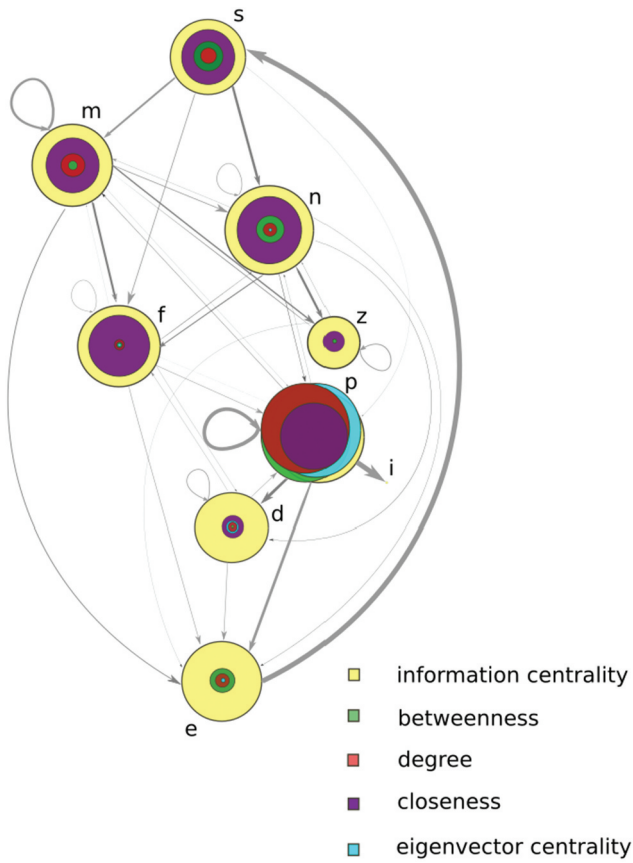

Figure 2. The MC diagram for the composite chain (the size of the nodes corresponds to their centrality measures, whereas the size of the arrows reflects the probability of transitions between nodes in H_Overall).

centrality measures; their measures are almost the same as those of proper names and nouns. While they constitute an important hub due to their direct connections to other important nodes, pronouns are not always the most crucial to the flow of information in a network. In linguistic terms, this implies that pronouns are less likely to be used at the beginning of the chain. However, once reference is established through alternative strategies such as metonymy or a noun, the subsequent use of pronouns becomes feasible.

Furthermore, metonymy and nouns tend to have relatively high values of betweenness and closeness centrality values. Also, betweenness centrality scores are in general slightly higher for nouns, which suggests that they have a greater global importance in a network, as compared to metonymy. This is also evidenced by the higher degree centrality values for metonymy, indicating its greater local significance (for the onset of the chain). Finally,

the analysis of information centrality measures demonstrates that all referential types have relatively high values: i.e. information flow within referential networks, passing through multiple nodes, is efficient.

4.2. Typicality

The typicality of reference chains, analysed through the fine-grained annotation, refers to the degree of predictability in transitioning from one referring expression to another. Although different transitions can be atypical for different handover meetings, it is possible to identify general patterns of atypicality. For example, consecutive noun phrases fall outside the typical pattern (e.g. *nobody needing palliative or oncology (1) just* ***that lady*** *(.)* ***the lady on trolley one***). Further, the transition from a pronoun to proper name is highly atypical (e.g. *D bay bed 3* ***he****'s been referred today I think [****FNLNM****]*), and it is less typical to observe the transition from a pronoun to LOCATION for PERSON metonymy (e.g. *trolley 7 [FNLNM] (.)* ***he****'s on a naloxone infusion* ***Trolley 7*** *Trolley 7 (.) he's on half hourly urm (.) obs and GCS*). In comparison, the transitions from metonymy to metonymy, from a pronoun to a pronoun, from a metonymy to proper name, from a noun phrase to a pronoun, and from a proper name to a pronoun are highly typical.

Generally, highly typical chains are longer (Dunn's test pairwise comparisons reveal statistically significant differences between the low-typicality and high-typicality groups, as well as between the medium-typicality and high-typicality groups; $p < 0.05$). Further, we used Pearson's chi-squared test to explore the association between the types of referential expressions and their frequencies across the three quantiles: low, medium and high. The test suggests that the distribution of referential expressions is significantly different among the quantiles (chi-squared = 38.209; $df = 16$, $p < 0.001$). The residual plot in Figure 3 illustrates how the distribution across quantiles differs. In the low-quantile group, we observe a significantly higher frequency of plural nouns and a lower frequency of proper names, descriptive nouns, post-copular metonymy and TREATMENT for PERSON metonymy. The medium quantile group is characterized by a high frequency of metonymy (*lm*, *pm* and *tm*) and a low frequency of nouns, plural nouns, descriptive nouns, and pronouns. Finally, the high-quantile group is distinguished by a high frequency of proper names, descriptive nouns, and nouns, coupled with a low frequency of all types of metonymies.

The correlation analyses and GAM modelling offered a broader perspective on the development of typical patterns across all four meetings. It revealed statistically significant, moderate associations between the typicality

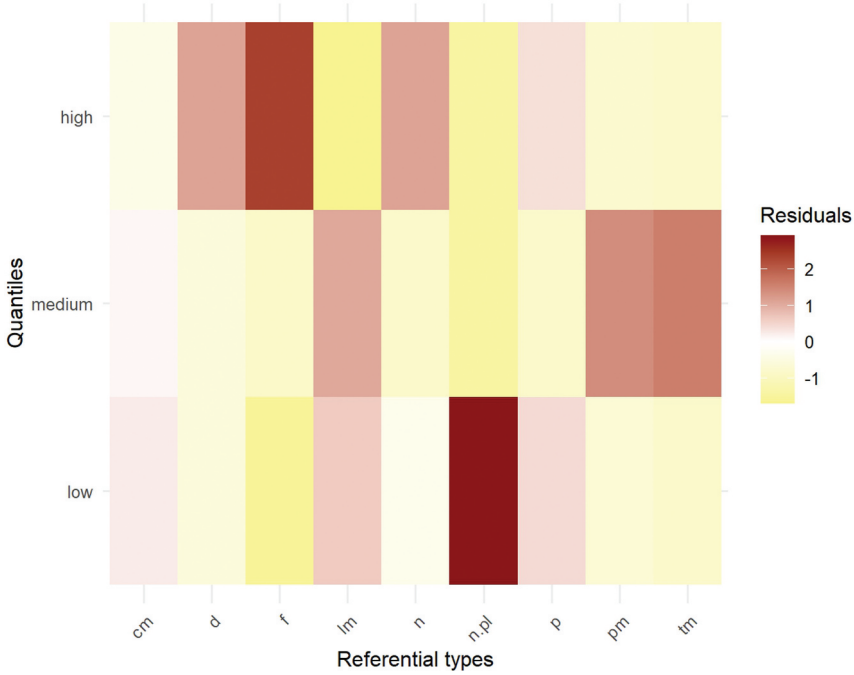

Figure 3. The plot of the standardised residuals across the three quantiles.

of the chains and their position in a handover meeting from its beginning to its end[12] ($r = 0.31$, $p = 0.001$), and the typicality and a length of a chain ($r = 0.56$, $p < 0.001$).

GAM modelling involved two nested models: (i) GAM with two predictors (the number of a handover meeting and the length of a chain); and (ii) GAM with three predictors (two terms from the first model and the position of the chain within a handover meeting). Their comparison with the ANOVA test confirmed superior statistical performance of the second model (Figure 4). The Analysis of Deviance Table shows that the second model has a lower residual deviance (0.98521 vs. 1.01642 in the first model; $p = 0.03$). The second model explains 47% of the variance in typicality and accounts for the 50.4% of deviance, suggesting a reasonable fit of the model to the data. Therefore, the inclusion of 'position' as a predictor improved the model's fit and predictive ability for typicality. However, the effect of the 'position' variable was not statistically significant ($p > 0.05$): while the position of a chain within a handover meeting is correlated with its typicality, the contribution of this variable to explaining the variation in the dependent variable is not statistically significant in the presence of the other predictors. The GAM analysis reveals a subtle increase in reference typicality towards the end of the session: i.e. as the handover meeting progresses, the efficiency of reference communication slightly increases.

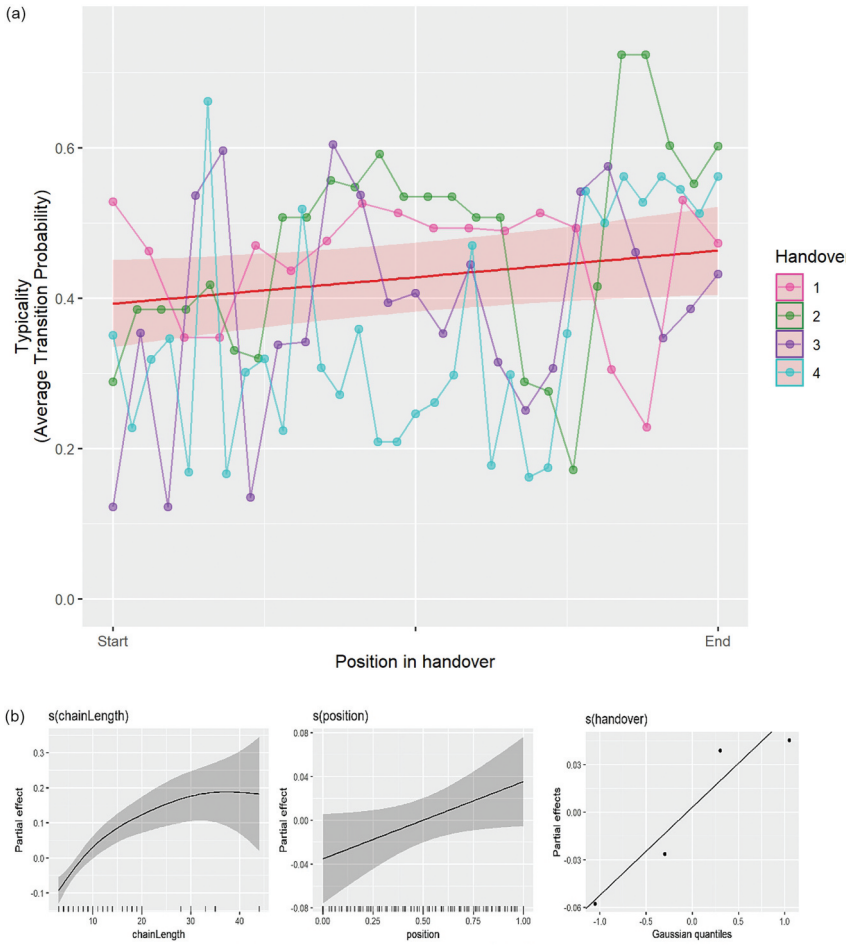

Figure 4. (a) The regression plot for the GAM model with the 3 predictors (points represent the value of the average transition probability in a chain, and colours represent handover meetings); (b) effect regression plots for the same model.

It is important to recognize that the presented GAM model exhibits a modest ascending slope, indicating a subtle yet gradual increase in referential typicality over the course of the sessions, from start to finish. This could be attributed to several factors, including the small sample size, the presence of noise in the data, the structure of the SPI form and the inherent complexities of building the model on time series. However, the aim of this analysis has been to test the hypothesis that reference tends to become more regular as communication progresses, and the model provides an indication that this trend may indeed be occurring. Therefore, this model can serve as a starting point for further research into the progression of reference over time and its regularization.

5. Discussion

Referential dynamics during handover meetings is flexible but predictable: the behaviour of referring expressions progresses in stages is influenced to some extent by preceding referential expressions, as indicated in the existing literature on various referential expression (e.g. Cowart & Cairns, 1987 for the transition between a cataphoric pronoun and a noun phrase; Gordon et al., 1993 for the transition between two proper names; Arnold et al., 2009 for the transitions between pronouns). The predictability of the referential types (up to 75%) indicates that reference to patients during handover meetings, based on the SPI form, is efficient. This is because the predictability of reference depends on the structured organization of reference information, which, in turn, promotes the efficiency in referential communication. The SPI form also accommodates variability in how that information is presented. The portion of variability unaccounted for by our VLMC models may stem from individual preferences in patient referencing. An example of individual preference can be seen in the lead nurse's tendency during handover meeting 3 (H3) to initiate referencing with a noun phrase.

Metonymy has been shown to introduce a second-order complexity to the VLMC models. It is largely associated with the beginning of a reference chain (patient-centric reference) or with metonymical sequences (location-oriented reference). From this, we can infer that metonymy triggers two distinct types of sentences: the first focuses on the patient, offering detailed information about the individual, while the second emphasizes spatial descriptions related to the patient's location. This is also supported by the graph analyses which revealed a higher local significance of metonymy due to its closer connections to the start node, as well as its increased probabilities of recurrence. Metonymy is also associated with a medium typicality. In patient-centric reference, LOCATION for PERSON metonymy as the first mention is preferred for referencing an individual patient, whereas CONDITION for PERSON and post-copular metonymy are more frequently used when referencing multiple patients.

Further, the second-order complexity emerges for a noun phrase and a pronoun in the overall model, which signifies that this association within the context of handover meetings becomes evident with more time and interactions. Although nouns are relatively often used as the first mention (especially, in the second part of handover meetings), the emerging dependency between a noun phrase and a pronoun conveys the meaning that noun phrases have a higher likelihood of occurring in the middle of the reference progression and are more likely to be followed by pronouns. Thus, this observation suggests that immediate co-reference and continuity in the subject (cf. Hickmann, 2002; Jisa, 2000; Le Mené et al., 2023) become particularly salient around the midpoint of

referencing, where maintaining coherence and flow in referential expressions appears especially crucial for sustaining clear communication. In addition, the dependency between a noun and a pronoun could be interpreted as the realization of the proposed link between recently mention referents and the immediate use of pronouns, as discussed in Arnold et al. (2009). This is also confirmed by the higher values of betweenness centrality of noun phrases (as compared to metonymy, for example) – meaning their higher global importance for referencing – and a closer connection of nouns to the end node and pronouns. We also observed that nouns, as compared to metonymy, have stronger connections to descriptive complex phrases and zero anaphora. Furthermore, unlike metonymy, noun phrases exclusively trigger patient-oriented sentences, offering specific details about the patients themselves without focusing on their spatial context or location.

In addition, singular nouns tend to occur more frequently in highly typical chains, whereas plural nouns in low typical chains. Prominently, in contrast to metonymical sequences, sequences of nouns have been identified as atypical. As established in the existing literature, noun-to-noun transitions are favoured for distant reintroduction, switching to subject position, and for other syntactic functions (de Weck et al., 2019, p. 300). The infrequency of noun-to-noun transition in handover meetings highlights the crucial role of maintaining immediacy and continuity of the subject in handover meetings. It may also suggest a narrower range of syntactic functions in referencing within this context, with topic shifts occurring more gradually rather than abruptly (i.e. distant reintroductions are exceedingly rare in the data).

The transitions from a proper name to a proper name are also infrequent and could primarily be ascribed to the need for correction of the initially mentioned proper name (*cf.* Gordon et al., 1993). In general, proper names are associated with highly typical reference chains.

Pronouns in the handover sessions have been identified as the most important in light of their connectivity to other important referring expressions in a chain, but in the context of information propagation, their significance is not always the foremost. Consecutive sequences of pronouns slightly reduce their prominence as the most central conveyers of information. Chains with long sequences of pronouns have been found in highly typical reference chains, which indirectly suggests three points. First, this suggests that the speaker's attention remains fully focused on a single referent, as it is established that dividing attention across multiple referents reduces the likelihood of pronoun use (Arnold, 2008, p. 520). Second, long sequences of pronouns maintain flow and coherence in reference and allow the focus of saying to shift towards other important details about a patient. Third, they suggest lesser visual salience of referents and a higher cognitive load of the speakers (Vogels et al., 2013).

Having substantiated the moderate yet statistically significant correlation between 'typicality' and 'position', along with confirming that the inclusion of 'position' augments the GAM model's predictive power, we can reasonably deduce that the impact of the position of a chain on its typicality is subtle yet discernible: i.e. the typicality of reference chains shows a minor rise by the end of a session. This effect is minor and to establish its significance, a larger dataset might be necessary. Nevertheless, the rise in typicality could hold significance within the framework of the Expectancy Hypothesis (Arnold, 2008). Based on this hypothesis, when speakers receive both textual and non-textual cues from their environment regarding a referent, their anticipation of that referent being mentioned again increases. As a result, the referent becomes more accessible in their minds. An increase of referent's accessibility due to a higher likelihood of its recurrent mention may also result in the process of referencing becoming more regular. Another plausible explanation of an increase of referencing typicality by the end of the session could be the warm-up effect of speaking. The initiation of speech may be difficult, but as speakers engage in conversation, their speech becomes more typical and fluent. With time, they adapt to their environment and synchronize more effectively with a developing discourse. However, a deeper exploration is essential to back up these conjectures.

The GAM model also establishes the impact of two other factors on referencing typicality: the length of the chain and handover meeting. The longer the chain, the more typical it is, because it tends to encompass a more complete spectrum of discourse stages of referencing. Further, the effect of a handover session signals individual differences in referencing.

Approximately 50% of the variance in typicality are accounted for by the GAM model, leaving the remaining half unaccounted for within this framework. There are other factors that also have an impact on how typical a reference chain is. As an illustration, the SPI form may influence the referencing process, with certain sections potentially facilitating smoother referencing. Further, various mental states of speakers are also helpful in explaining a degree of referential typicality. If we look at the atypical transitions mentioned earlier – for example, the transition from a noun phrase to a noun phrase, from a pronoun to a proper name and from a pronoun to metonymy – we can see that referential atypicality occurs due to hesitation/hedging or the need to clarify information about a patient:

(1) *D bay bed 3* ***he****'s been referred today I think* ***[FNLNM]***
(2) *nobody needing palliative or oncology (1) just* ***that lady*** *(.)* ***the lady on trolley one*** *but she's assigned to gastro for this admission*
(3) *(.) trolley 7 [FNLNM] (.)* ***he****'s on a naloxone infusion* ***Trolley 7*** *Trolley 7 (.) he's on half hourly urm (.) obs and GCS*

Hence, an atypical referential transition is not solely an uncommon co-occurrence of referential types; it also signifies an additional cognitive burden that contributes to communication challenges.

Finally, it is crucial to mention one major inherent limitation of the average transition probability. This measure does not capture such referential anomalies as the use of indefinite article before a proper name or the omission of determiners in anaphoric complex phrases, which we labelled with the fine-grained annotation. This is because these are anomalies that reflect grammatical relationships within constituents of a referring expression and not a relationship between referring expressions, although it should be noted that these anomalies also signal extra cognitive load for speakers during handover meetings.

6. Conclusions

Reference to patients in handover meetings is a dynamic process that evolves over discrete time intervals and thus can be predicted to a relatively high degree of accuracy using the VLMC modelling. The performed analyses have shown that metonymy and a noun phrase have two distinct profiles. We have also demonstrated that the typicality of a reference chain is influenced by its length, individual referencing preferences of speakers and the time point within a handover meeting in which referencing is made. A subtle increase of referential typicality by the end of handover sessions can be attributed to the growing accessibility of referents in the minds of speakers and to the speech 'warming-up' phenomenon. Additional factors contributing to the typicality of reference chains encompass the SPI form, along with mental states of speakers pertaining to information processing and delivery.

Notes

1. We would like to express our gratitude to Sam Haworth and Harriot Lloyd for their invaluable assistance with data transcription.
2. Cardiac arrest is a medical emergency condition whereby the regular contraction of the heart muscle stops unexpectedly.
3. NFR stands for 'Not for Resuscitation'. NFR refers to the decisions made and documented, suggesting that Cardiopulmonary Resuscitation not be performed in the event of patient's cardiac arrest or death.
4. The symbol (.) serves as an indicator of a pause in the text.
5. Reference chains are unlikely to cross as they would in most types of discourse. This is because the discussion of a given patient continues until a new patient is mentioned or a new section is started. Although a chain can be resumed, such occurrences are infrequent.

6. The introduction of these additional states was motivated by the Markov chain methodology, which necessitates the evaluation of both initial and terminal conditions within a system.
7. When we mention the absence of something, we refer to a distinct set of entities where the absent item might have been found.
8. In our data, the only instances of singleton reference chains are chains with post-copular metonymy and the determiner 'no': e.g. *We've had no cardiac arrests*. It was formalized as follows: '*s, pm, e*'.
9. An analogy of how the VLMC works could be a chess game, where each move depends not only on the rules of the game, but also on the current position of the players' chess pieces. Similarly, VLMC transitions between states depend both on the probabilities associated with potential transitions and on the previous observations of states.
10. Transition in MC denotes moving from one state (i.e. referring expression) to another within a chain.
11. For fitting the VLMC models, the pruning cut-off was set up to 6 (which corresponds to a significance level of 1%) to avoid information loss.
12. For a given handover with N chains in order from i = 1 to N, the 'position' variable for a chain was set to (i-1)/(*N*-1), so that the variable ranged from 0 (the first chain) to 1 (the last chain).

Disclosure Statement

No potential conflict of interest was reported by the author(s).

Data Availability Statement

The formalized version of the data is presented in the script and is accessible via the following link: https://dataverse.harvard.edu/privateurl.xhtml?token=322b9344-1f63-44d1-b126-8bceea751473.

There are two other versions of the data: (i) the formalized chains and their one-to-one correspondence to the actual linguistic utterances, available in an Excel format, and (ii) actual transcripts of the nurse handover meetings. The former is available on request from the corresponding author (Krykoniuk K.). However, we cannot authorise passing on the transcripts owing to the sensitive nature of the data and ethics constraints. The data are not publicly available due to the sensitivity of information and due to the fact that researchers have ongoing research plans involving this data, which necessitates controlled access at this time.

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Appendix: The template of the Safer Patient Initiative Form

GIG NHS

SAFER PATIENT INITIATIVE
work cycle
SAFETY BRIEFING

To record the safety briefing at ward handover on each shift

Date of audit ☐☐ / ☐☐ / ☐☐

Ward **MAU/D1WEST**

Shift ☐ Early ☐ Late ☐ Night

Representation at handover

Trained nursing staff ☐ yes ☐ no

Untrained nursing staff ☐ yes ☐ no

	SAFETY BRIEFING TOPICS	PLEASE TICK	COMMENTS
1	Cardiac Arrest (within 12 hours)	Yes ☐ No ☐	
2	NFR		
3	Falls		
4	At risk of Falls	Yes ☐ No ☐	
5	POVA/Sectioned Abscond/Self Discharge	Yes ☐ No ☐	
6	Drug Error/Clinical Incident	Yes ☐ No ☐	
7	Patients Giving Concern	Yes ☐ No ☐	
8	Patients with PU Rental air mattresses / Repose cushion	Yes ☐ No ☐	
9	CD check Pt own CD Cardiac arrest drugs	Yes ☐ No ☐	
10	COPD Patients on bundle	Yes ☐ No ☐	
11	Blood Transfusions	Yes ☐ No ☐	
12	Infection/Isolation	Yes ☐ No ☐	
13	Patients needing palliative /oncology service	Yes ☐ No ☐	
14	Check Resus Trolleys (NIGHTS)	Yes ☐ No ☐	Done by: Done by:
15	Hand Hygiene Audit	Yes ☐ Yes ☐	Thursday Night Done by: Sunday Day Done by:
16	PU Audit (DAY Safety crosses	Yes ☐ No ☐	Done by: Done by:
17	Boards Updated	Yes ☐	
18	Calibration bm machines And check/stock boxes	Yes ☐ No ☐	
19	Staffing Issues	Yes ☐ No ☐	
20	Patient returning/ VIP Notes location	Yes ☐ No ☐	
21	Patients referred to outreach	Yes ☐ No ☐	
22	Medication lockers checked for patients own	6 am ☐	
	R RAILS Number of admissions		Number of transfers
	Number of patients on ward		
	How many patients at risk NEWS 4 +		
	How many patients had appropriate response		
	How many patients diagnosed with sepsis		

Briefing by ..... (Print name)
Signed .....

DONT FORGET CANNULA /CATHETER BUNDLES